

Draft: Work in Progress

General Mission Analysis Tool (GMAT) User's Guide

DRAFT



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Chapter 1

Configuring Objects/Resources

There are numerous objects, also called resources, that the user can create and configure in GMAT. Examples include Spacecraft, Propagators, Coordinate Systems, and Plots. Each of these resources are configurable from the script and GUI and this chapter discusses how to configure all objects regardless of your chosen interface.

Each section in this Chapter is devoted to a specific type of object. For each object, we present a screen capture of the dialogue box used to configure the object from the GUI. Next we present a short explanation of how to use the dialogue box to configure common types. Finally, a table is presented that describes in detail each settable field for the object. The detail includes default values, allowable inputs and ranges, and a text description of the field.

Let's begin by looking at the Spacecraft object.

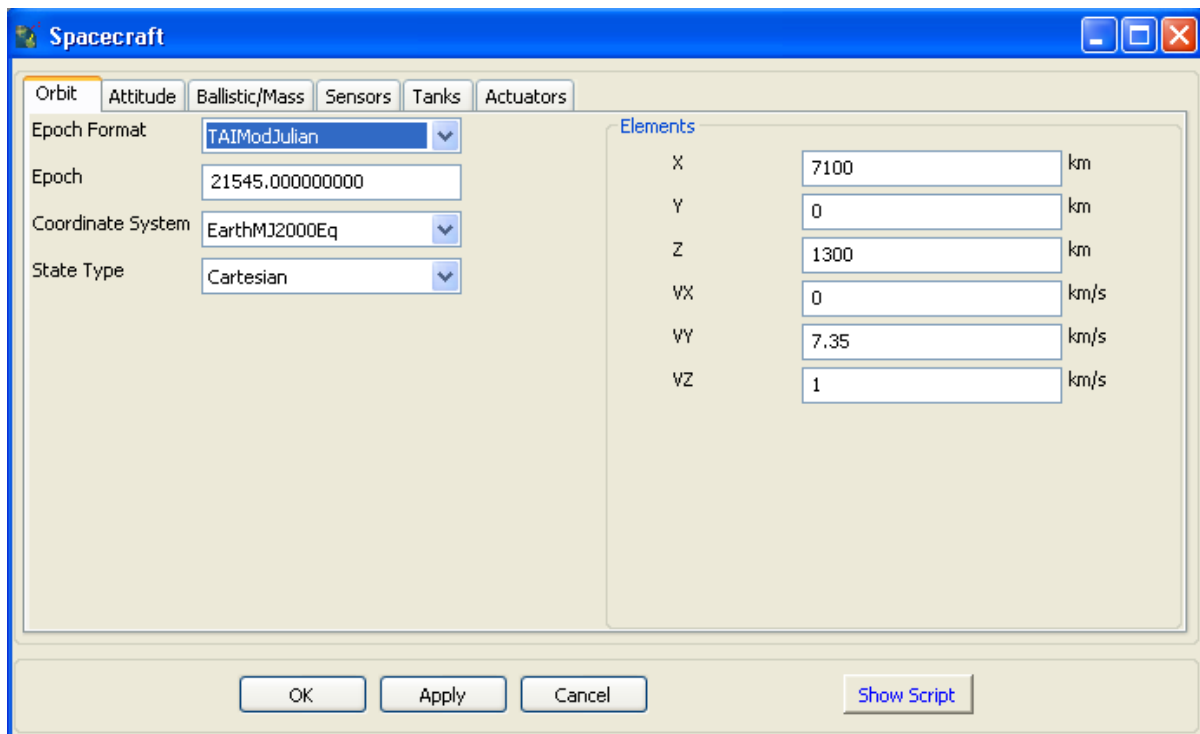


Figure 1.1: Spacecraft Dialogue Box / Orbit Tab

1.0.1 Overview of the Spacecraft Object

The Spacecraft object is one of the most important resources in GMAT and can be configured in numerous ways. For most mission applications, GMAT's primary use and function is to simulate and model how an actual spacecraft would behave (or behaved) in a flight situation. You do this by creating and configuring spacecraft objects, GMAT's mathematical model of real-world spacecraft, and by issuing commands such as **Propagate** for GMAT to apply to the spacecraft model.

The types of parameters and settings on the Spacecraft Object fall into several categories: Orbit, Attitude, Ballistic/Mass, Sensors, Tanks, and Actuators. Each of these is configured on a separate tab on the Spacecraft dialog box. For example, you can configure the initial state and epoch on the Orbit tab, and the , the mass and ballistic properties on the Ballistic/Mass tab. In the following sections we discuss each tab in detail.

Possible Coupling with Other Objects

A Spacecraft Requires Other Objects/Commands of Type: None.

A Spacecraft has the Potential to Couple with Objects/Commands of Type: Tank, Thruster, Differential Corrector, fminconOptimizer, XYPlot, OpenGLPlot, ReportFile, Variables/Arrays, Coordinate System, MATLAB Function, BeginFiniteBurn, EndFiniteBurn, Function Call, Assignment Command, Maneuver, Propagate, Report, Save, Script Event, If, For, While, Vary, Achieve, Minimize, NonlinearConstraint.

1.0.2 Spacecraft Orbit Tab

The Spacecraft/Orbit tab is used to set the orbit state and epoch and is illustrated in Fig. 2.1. On this tab, you can choose the epoch, coordinate system, and the state representation in which to enter initial condition information. There are three groups on the Spacecraft/Orbit tab: Epoch, State Configuration, and State Vector. Below, we discuss each group in detail.

Epoch Group

The Epoch group allows you to select the time system and time format in which to enter the initial Spacecraft epoch. Several choices are available including **A1ModJulian**, **TA1ModJulian**, **UTCModJulian**, **TTModJulian**, **A1Gregorian**, **TA1Gregorian**, **UTCGregorian**, **TTGregorian** . An epoch can be provided in either the Modified Julian Date (with reference epoch 05 Jan 1941 12:00:00.000 TAI) or Gregorian Date formats. As an example, the J2000 Epoch should be expressed using the Gregorian date format as 01 Jan 2000 12:00.000 (TDB).

Note that if you change the **EpochFormat** combo box, and have defined the spacecraft state with respect to a time dependent coordinate system, the state vector representation in the GUI does *not* change. For example, if you define a Spacecraft's state with respect to the Earth Fixed system, and then change the epoch, you have not changed the state vector in the Earth Fixed system and therefore the values in the GUI do not change. However, change the epoch does change the inertial state that results from converting the Earth Fixed state to the inertial state. This is because the orientation of the Earth Fixed frame is different at the new epoch, and so the transformation to the inertial frame yields a new results.

State Configuration Group

The State Configuration group allows the user to select the coordinate system and state representation for a Spacecraft's initial conditions. The **StateType** pull-down menu contains several options for the orbit state Representation including **Cartesian**, **Keplerian**, **ModifiedKeplerian**, **SphericalAZFPA**, **SphericalRADEC**, **Equinoctial** . The **Coordinate System** pull-down menu allows you to specify the Coordinate System in which the Spacecraft's initial conditions are expressed. The default coordinate systems always appear and are **EarthMJ2000Eq**, **EarthMJ000Ec**, and **EarthFixed**. If you create other user defined Coordinate Systems, they also appear in the **Coordinate System** drop-down menu. The numeric values contained in the State Vector group are dynamically updated as changes are made to **State Type** and **Coordinate System**. For example, if you enter a state vector in **EarthMJ2000Eq**, hit apply, and change the Coordinate System pull-down to **Earth Fixed**, the GUI will reconfigure to show the equivalent state vector in the Earth Fixed system at the defined epoch.

State Vector Group

The State Vector group contains the numeric values for a Spacecraft's initial conditions. The state vector is shown in the selected state representation as defined in **State Type** and is expressed in the requested coordinate system defined by **Coordinate System**. The labels, units, and numeric values dynamically respond to changes in either the **Coordinate System** or **State Type** pull-down menus. You can use the State Vector to group to define a spacecraft's initial conditions in any coordinate system, or to view the spacecraft's state in any coordinate system.

A detailed discussion of all fields on the Spacecraft Orbit tab is found in Table 2.1. Now let's look at the Spacecraft Attitude tab.

1.0.3 Spacecraft Attitude Tab

This Tab is not currently supported in GMAT. It is included only to illustrate look-and-feel of future enhancements.

1.0.4 Spacecraft Ballistic/Mass Tab

The Ballistic/Mass tab, shown in Fig. 2.2 is used to set spacecraft mass and ballistic properties. On this panel, you can set properties such as **DryMass**, **DragArea**, and **SRPArea** among others. GMAT currently only supports a point-mass spacecraft model. In the future GMAT will support a higher fidelity spacecraft model, and this panel will allow you to set the spacecraft moments of inertia and other properties.

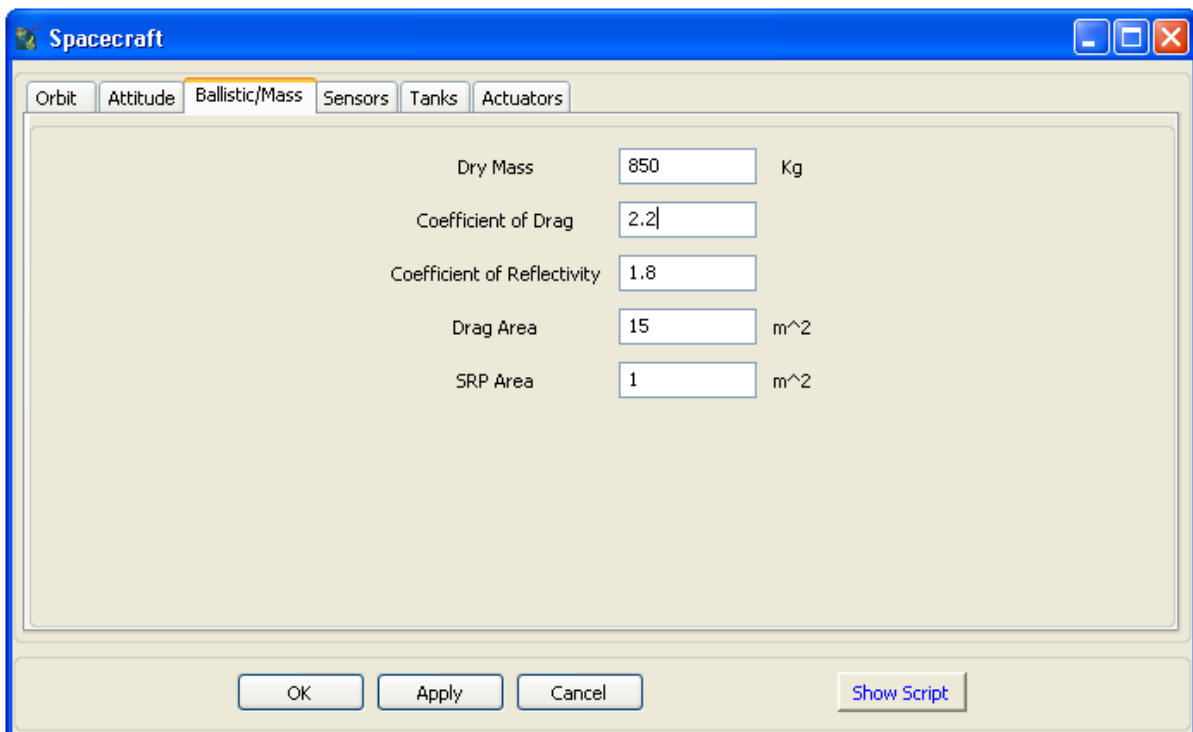


Figure 1.2: Spacecraft Dialogue Box / Ballistic/Mass Tab

Ballistics Group

The Ballistics group allows the user to specify spacecraft physical properties that are used to calculate properties such as the ballistic coefficient. A detailed discussion of all fields on the Spacecraft Ballistic/Mass tab is found in Table 2.3. Now let's look at the Sensors tab.

1.0.5 Spacecraft Sensors Tab

This Tab is not currently supported in GMAT.

1.0.6 Spacecraft Tanks Tab

The Spacecraft/Tanks tab allows you to add multiple tanks to a spacecraft. Tanks are created separately from spacecraft and if you have not created any tanks, the Available Tanks list will appear empty. You can add an existing tank to a spacecraft by selecting the desired tank using a left mouse click and then using a left mouse click on the right-arrow icon. If there are no existing tanks, go to the resource tree, right click on the Hardware folder that appears as a subfolder to spacecraft, and select Add/Fuel Tank.

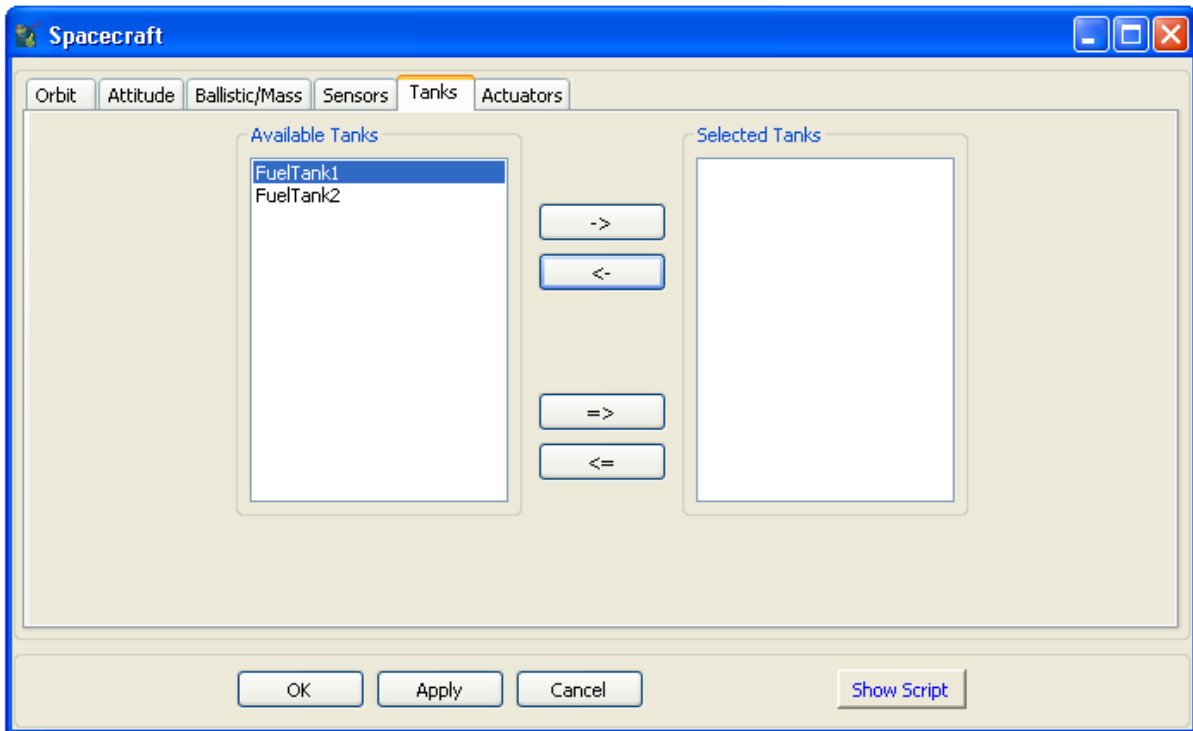


Figure 1.3: Spacecraft Dialogue Box / Tanks Tab

1.0.7 Spacecraft Actuators Tab

The spacecraft/Actuators tab allows you to add multiple actuators to a spacecraft. Currently the only actuator that GMAT supports are thrusters. You must create a thruster before you can add it to a spacecraft. If you have not created any thrusters, the Available Thrusters list will appear empty. You can add existing thrusters to a spacecraft by selecting the desired thruster using a left mouse click and then using a left mouse click on the right-arrow icon. To create a Thruster, go to the resource tree, right click on the Hardware folder that appears as a subfolder to spacecraft, and select Add/Thruster.

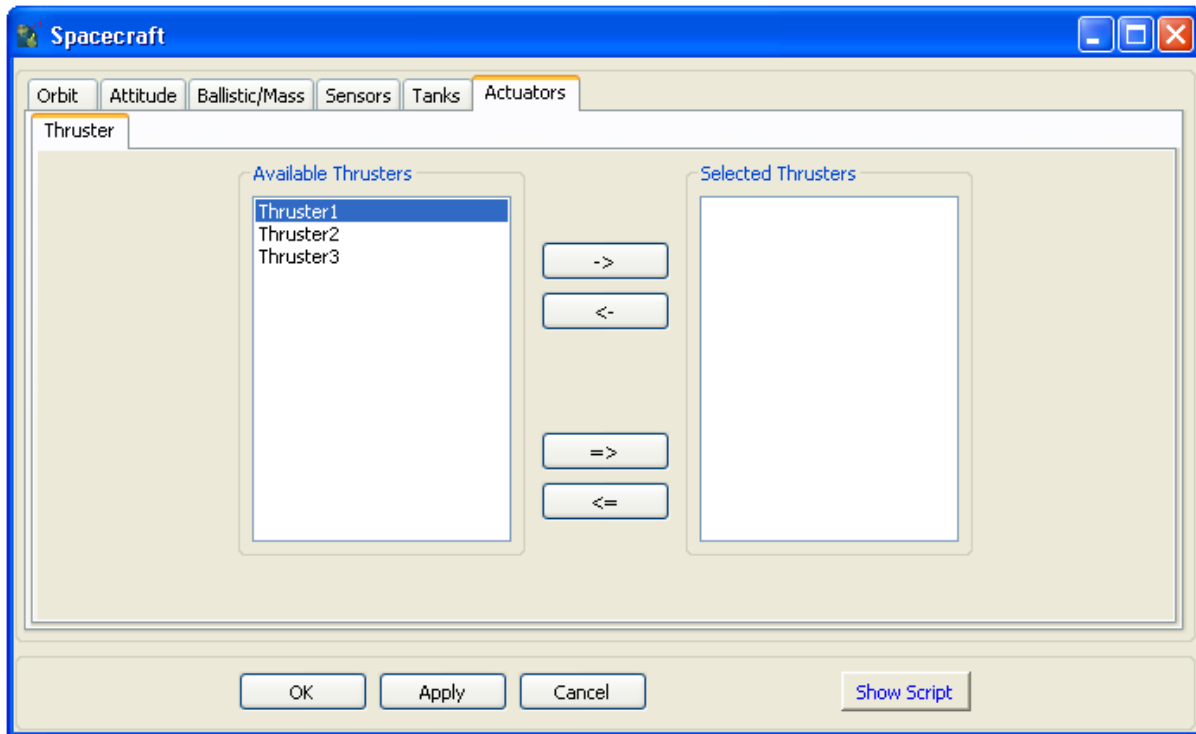


Figure 1.4: Spacecraft Dialogue Box / Actuators Tab

Table 1.1: Fields Associated with a Spacecraft Orbit State
(Orbit Tab)

| Field | Options and Description |
|-------------------|--|
| StateType | Default: Cartesian. Options: [Cartesian, Keplerian, ModifiedKeplerian, SphericalAZFPA, SphericalRADEC, Equinoctial]. The StateType field allows the user to configure the type of state vector that they wish to use. The Statetype field has a dependency upon the CoordinateSystem field. If the Coordinate System chosen by the user does not have a gravitational body at the origin, then the state types Keplerian, ModifiedKeplerian, and Equinoctial are not permitted. This is because these state types require a μ value. Units: N/A. When the Keplerian or ModifiedKeplerian state types are selected, the Anomaly Type field becomes visible. |
| Coordinate System | Default: EarthMJ2000Eq. Options: [EarthMJ2000Eq, EarthMJ2000Ec, EarthFixed, or any user defined system]: The Coordinate System field allows the user to choose which coordinate system with which to define the orbit state vector. The CoordinateSystem field has a dependency upon the StateType field. If the Coordinate System chosen by the user does not have a gravitational body at the origin, then the state types Keplerian, ModifiedKeplerian, and Equinoctial are not permitted. This is because these state types require a μ value. Units: N/A. |

Table 1.1: (Fields Associated with a Spacecraft Orbit State (Orbit Tab). continued)

| Field | Options and Description |
|-------------|--|
| EpochFormat | Default: <code>TAIModJulian</code> . Options: [<code>A1ModJulian</code> , <code>TAIModJulian</code> , <code>UTCModJulian</code> , <code>TTModJulian</code> , <code>A1Gregorian</code> , <code>TAIGregorian</code> , <code>UTCGregorian</code> , <code>TTGregorian</code>]: The <code>DateFormat</code> field allows the user to specify the format for defining a spacecraft's initial epoch. <code>DateFormat</code> determines both the time system (TAI, TT, etc) and the time format (MJD or Gregorian). Units: N/A. |
| Epoch | Default: 21545.000000000. Options: [See Comments]: The <code>Epoch</code> field allows the user to specify the initial spacecraft epoch. The format of the epoch must be consistent with the <code>DateFormat</code> field. If <code>DateFormat</code> is of the "MJD" type, then the epoch is in Modified Julian format. If <code>DateFormat</code> is a "Gregorian Type", the format is similar to 01 Jan 2000 12:00:00.000. Units: MJD - days, Gregorian - N/A. |
| AnomalyType | Default: <code>TA</code> . Options: [<code>TA</code> , <code>MA</code> , <code>EA</code> , <code>HA</code>]: The <code>Epoch</code> field allows the user to specify the to select the <code>AnomalyType</code> needed for the <code>Keplerian</code> or <code>ModifiedKeplerian</code> spacecraft state. In the scripting environment, <code>AnomalyType</code> is not used. Units: N/A. |

Fields associated with Cartesian state.

| | |
|----|--|
| X | Default: 7100. Options: [Real Number]: <code>X</code> is the x-component of the Spacecraft state in the coordinate system chosen in the Spacecraft <code>CoordinateSystem</code> field. Units: km. |
| Y | Default: 0. Options: [Real Number]: <code>Y</code> is the y-component of the Spacecraft state in the coordinate system chosen in the Spacecraft <code>CoordinateSystem</code> field. Units: km. |
| Z | Default: 1300. Options: [Real Number]: <code>Z</code> is the z-component of the Spacecraft state in the coordinate system chosen in the Spacecraft <code>CoordinateSystem</code> field. Units: km. |
| VX | Default: 0. Options: [Real Number]: <code>VX</code> is the x-component of the Spacecraft velocity in the coordinate system chosen in the Spacecraft <code>CoordinateSystem</code> field. Units: km/sec. |
| VY | Default: 7.35. Options: [Real Number]: <code>VY</code> is the y-component of the Spacecraft velocity in the coordinate system chosen in the Spacecraft <code>CoordinateSystem</code> field. Units: km/sec. |
| VZ | Default: 1.0. Options: [Real Number]: <code>VZ</code> is the z-component of the Spacecraft velocity in the coordinate system chosen in the Spacecraft <code>CoordinateSystem</code> field. Units: km/sec. |

NOTE: Default values for the remaining state types are obtained through transformations of the default `Cartesian` spacecraft state values. The `Keplerian`, `ModifiedKeplerian`, and `Equinoctial` are dependant on the origin of the `CoordinateSystem`, because the state types require a μ value.

Table 1.1: (Fields Associated with a Spacecraft Orbit State (Orbit Tab). continued)

| Field | Options and Description |
|---|--|
| Fields associated with Keplerian state. | |
| SMA | Default: 7191.938817629. Options: [Real Number $\neq 0$]: The SMA field is the spacecraft orbit's osculating Keplerian semimajor axis in coordinate system chosen in the Spacecraft CoordinateSystem field. SMA must be strictly greater than or less than zero. For circular and elliptical ($0 \leq \text{ECC} < 1$) orbits SMA should only be a positive Real Number and for hyperbolic orbits ($\text{ECC} > 1$) SMA should only be a negative Real Number. GMAT does not support the creation of parabolic orbits. Units: km. |
| ECC | Default: 0.024549749. Options: [$0 \leq$ Real Number, $\text{ECC} \neq 1$]: The ECC field is the spacecraft orbit's osculating eccentricity. ECC must be greater than or equal to zero but not equal to one (GMAT does not support parabolic orbits). Note: ECC can be greater than one. See the SMA description for additional restrictions to the allowable values of ECC. Units: Dimensionless. |
| INC | Default: 12.850080057. Options: [Real Number]: The INC field is the spacecraft orbit's osculating inclination, in degrees, w/r/t to the selected coordinate system. Units: degrees. |
| AOP | Default: 314.190551536. Options: [Real Number]: The AOP field is the spacecraft orbit's osculating argument of periapsis, in degrees, w/r/t to the selected coordinate system. Units: degrees. |
| RAAN | Default: 306.614802195. Options: [Real Number]: The RAAN field is the spacecraft orbit's osculating right ascension of the ascending node, in degrees, w/r/t to the selected coordinate system. Units: degrees. |
| TA | Default: 99.887749332. Options: [Real Number]: The TA field is the spacecraft orbit's osculating true anomaly. Units: degrees. |
| MA | Default: 97.107826639. Options: [Real Number]: The MA field is the spacecraft orbit's osculating mean anomaly. Units: degrees. |
| EA | Default: 98.498977103. Options: [Real Number]: The EA field is the spacecraft orbit's osculating eccentric anomaly. Units: degrees. |
| HA | Default: 0.000000000. Options: [Real Number]: The HA field is the spacecraft orbit's osculating hyperbolic anomaly. Units: degrees. |
| Fields associated with Modified Keplerian state. | |
| RadApo | Default: 7015.378524789. Options: [Real Number $\neq 0$]: The RadApo field is the spacecraft orbit's osculating radius of apoapsis. RadApo must be strictly greater than or less than zero. When RadApo is negative, the orbit is hyperbolic. Units: km. |

Table 1.1: (Fields Associated with a Spacecraft Orbit State (Orbit Tab). continued)

| Field | Options and Description |
|--------|--|
| RadPer | Default: 7368.4991104681 Options: [Real Number > 0]: The RadPer field is the spacecraft orbit's osculating radius of periapsis. RadPer must be greater than zero. Units: km. |
| INC | See the Keplerian state section for a description on this field. |
| AOP | See the Keplerian state section for a description on this field. |
| RAAN | See the Keplerian state section for a description on this field. |
| TA | See the Keplerian state section for a description on this field. |
| MA | See the Keplerian state section for a description on this field. |
| EA | See the Keplerian state section for a description on this field. |
| HA | See the Keplerian state section for a description on this field. |

Fields associated with SphericalAZFPA state.

| | |
|------|--|
| RMAG | Default: 7218.03297304. Options: [Real Number > 0]: The RMAG field allows the user to set the magnitude of the spacecrafts position vector. Units: km. |
| RA | Default: 0. Options: [Real Number]: The RA field allows the user to set the spacecraft's right ascension. Units: degrees. |
| DEC | Default: 10.3758449200. Options: [Real Number]: The DEC field allows the user to set the spacecraft's declination. Units: degrees. |
| VMAG | Default: 7.41771528167. Options: [Real Number ≥ 0]: The VMAG field allows the user to set the magnitude of the spacecraft's velocity. Units: km/sec. |
| AZI | Default: 82.377421681. Options: [Real Number]: The AZI field allows the user to set the spacecraft's azimuth angle. Units: degrees. |
| FPA | Default: 88.60870365370. Options: [Real Number]: The FPA allows the user to set a spacecraft's flight path angle. Units: degrees. |

Fields associated with SphericalRADEC state.

| | |
|------|--|
| RMAG | See the SphericalAZFPA state section for a description on this field. |
| RA | See the SphericalAZFPA state section for a description on this field. |
| DEC | See the SphericalAZFPA state section for a description on this field. |
| VMAG | See the SphericalAZFPA state section for a description on this field. |

Table 1.1: (Fields Associated with a Spacecraft Orbit State (Orbit Tab). continued)

| Field | Options and Description |
|---|--|
| RAV | Default: 90. Options: [Real Number]: The RAV field allows the user to set the right ascension of the spacecraft's velocity. Units: degrees. |
| DECV | Default: 7.7477720361. Options: [Real Number]: The DECV field allows the user to set the declination of the spacecraft's velocity. Units: degrees. |
| Fields associated with Equinoctial elements. | |
| SMA | See the Keplerian state section for a description on this field. |
| h | Default: -0.024234314. Options: [Real Number]: The h field is the projection of the eccentricity vector onto the y_{ep} axes. The \mathcal{F}_{ep} system is a system used in calculating the equinoctial elements and is beyond the scope of this discussion. The GMAT Mathematical Specifications document discusses \mathcal{F}_{ep} and the calculation of the equinoctial elements in detail. Units: None. |
| k | Default: -0.003922779. Options: [Real Number]: The k field is the projection of the eccentricity vector onto the x_{ep} axes. The \mathcal{F}_{ep} system is a system used in calculating the equinoctial elements and is beyond the scope of this discussion. The GMAT Mathematical Specifications document discusses \mathcal{F}_{ep} and the calculation of the equinoctial elements in detail. Units: None. |
| p | Default: -0.090388347. Options: [Real Number]: The p field is the projection of the N vector onto the y_{ep} axes. The N vector and the \mathcal{F}_{ep} system are used in calculating the equinoctial elements and are beyond the scope of this discussion. The GMAT Mathematical Specifications document discusses N and \mathcal{F}_{ep} and the calculation of the equinoctial elements in detail. Units: None. |
| q | Default: 0.067164549. Options: [Real Number]: The q field is the projection of the N vector onto the x_{ep} axes. The N vector and the \mathcal{F}_{ep} system are used in calculating the equinoctial elements and are beyond the scope of this discussion. The GMAT Mathematical Specifications document discusses N and \mathcal{F}_{ep} and the calculation of the equinoctial elements in detail. Units: None. |
| MeanLongitude | Default: 3.16359946. Options: [Real Number]: The MeanLongitude field is the the spacecraft's mean longitude. The GMAT Mathematical Specifications document discusses mean longitude and the calculation of the equinoctial elements in detail. Units: degrees. |

Table 1.2: Fields Associated with Spacecraft Physical Properties (Ballistic/Mass Tab)

| Field | Options and Description |
|-----------------|--|
| DryMass | Default: 850. Options: [Real Number ≥ 0]: The DryMass field allows the user to specify the mass of the spacecraft structure, but does not include the mass of tanks, thrusters, or fuel. Units: kg. |
| Cd | Default: 2.2. Options: [Real Number ≥ 0]: The Cd field allows the user to specify the spacecraft's drag coefficient. Units: None. |
| Cr | Default: 1.8. Options: [Real Number ≥ 0]: The Cr field allows the user to specify the spacecraft's coefficient of reflectivity. Units: None. |
| DragArea | Default: 15. Options: [Real Number ≥ 0]: The DragArea is the effective spacecraft area used in calculate the force due to drag. Units: m^2 . |
| SRPArea | Default: 1. Options: [Real Number ≥ 0]: The SRPArea is the effective spacecraft area used in calculate the force due to solar radiation pressures. Units: m^2 . |

Table 1.3: Fields Associated with a Spacecraft Ballistic and Mass Properties

| Field | Options and Description |
|-----------------|--|
| Cd | Default: 2.2. Options: [Real Number > 0]: Cd is the spacecraft's drag coefficient. Cd must be greater than 0. Units: Dimensionless. |
| Cr | Default: 2.2. Options: [$0 \leq$ Real Number ≤ 2.0]: Cr is the spacecraft's coefficient of reflectivity. Cr must be greater than 0. Units: Dimensionless. |
| DragArea | Default: 15.0. Options: [Real Number > 0]: The DragArea is the area of the spacecraft that is used in calculating atmospheric drag. DragArea must be greater than 0. Units: m^2 |
| SRPArea | Default: 1.0. Options: [Real Number > 0]: The SRPArea is the area of the spacecraft that is used in calculating the force due to solar radiation pressure. SRPArea must be greater than 0. Units: m^2 |
| DryMass | Default: 850.0. Options: [Real Number > 0]: The DryMass is the mass of the spacecraft without the mass of tanks and fuel. DryMass must be greater than 0. Units: kg |

1.0.8 Overview of the Propagator Object

In GMAT, a Propagator is a combination of an integrator and a force model. Hence, a Propagator contains a physical model of the space environment that is used to model the motion of a spacecraft as it moves forwards or backwards in time (VOP formulation is not currently supported). You configure a Propagator by selecting among different numerical integrators and environment models to create a Propagator appropriate to the flight

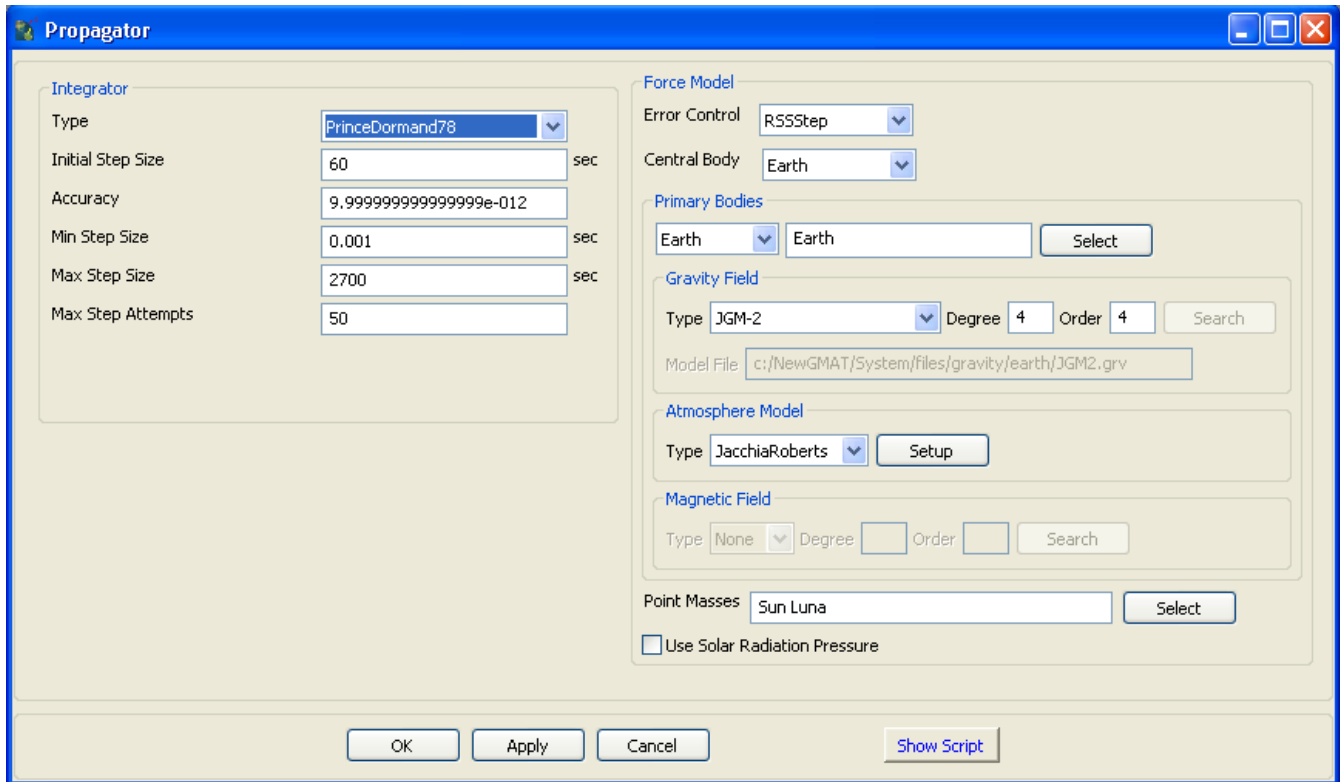


Figure 1.5: Propagator Dialogue Box

regime of spacecraft your mission. GMAT supports the following various numerical integrators: `RungeKutta89`, `RungeKutta68`, `RungeKutta56`, `PrinceDormand45`, `PrinceDormand78`, `BulirschStoer`, `AdamsBashforthMoulton`. Force models supported by GMAT include point mass and non-spherical gravity, atmospheric drag (Earth), and solar radiation pressure

To propagate spacecraft in GMAT, you first create and configure a Propagator object in the script or in the Resource Tree. Then, in the mission sequence, you create a Propagate Event, the topic of Chapter ??, and select among previously existing Propagators and Spacecraft. Hence, a Propagator is different from a Propagate Event: A Propagator is a resource and is found in the GUI under the resource tree, a Propagate Event is configured under the Mission Tree and is how you instruct GMAT to propagate spacecraft.

The Propagator dialogue box is illustrated in Fig. 1.5 and contains two group boxes: the Integrator group and the Force Model group. In this Chapter, we discuss the items in each group on the Propagate Panel. We present how to configure a propagator and discuss all possible user settable fields in detail.

Possible Coupling with Other Objects

A Propagator Requires Other Objects/Commands of Type: Force Model (Script Only). (Note: There are slight differences in how you configure a Propagator in the script and GUI and we refer you to the script example shown in the next section for details. Effort has been made to reduce any difference between the script and GUI. Future versions of GMAT will address this problem with the Propagator object.

A Propagator has the Potential to Couple with Objects/Commands of Type: Propagate.

1.0.9 Features of the Propagator Dialog Box

The Propagator Dialogue Box contains two groups boxes: Integrator and Force Model. You select and configure a numerical integrator using the Integrator group and a Force Model in the Force Model group. Let's begin by looking

at the Integrator group.

Integrator Group

The Integrator group allows you to select and configure a numerical integrator appropriate to your application. You select the type of numerical integrator in the **Type** pull-down menu. After selecting the integrator type, the fields below the **Type** pull-down menu dynamically configure to allow you to set relevant parameters for the selected integrator type. All integrators except for Adams-Bashforth-Moulton (ABM) are configured using the same fields. The ABM integrator has the following additional fields: **MinIntegrationError** and **NomIntegrationError**

Table 2.8 contains a detailed discussion of each user-settable field for a numerical integrator.

Force Model Group

The Force Model group allows you to configure a force model appropriate to the flight regime of your application. The central body of propagation and error control method are also defined here. On a Propagator, GMAT classifies all celestial bodies into two mutually exclusive categories: Primary Bodies, and Point Masses. Primary bodies can have a complex force model that includes non-spherical gravity, drag, and solar radiation pressure. Point mass bodies only have a spherical point-mass gravitational force.

While the Propagate dialogue box is designed to support multiple primary bodies, GMAT currently only supports a single primary body per propagator. You can add a Primary Body by clicking the **Select** button in the Primary Bodies group box. Once you have added a Primary Body (or multiple bodies in future versions), the pull down menu allows you to configure the force model for each Primary Body. The text box, next to the **Select** button contains a list of all Primary Bodies so you can see which bodies are being treated with complex force models. In future versions, GMAT will support multiple primary bodies on a propagator allowing you to use a non-spherical gravity model for the Earth and Moon simultaneously.

Configuring certain fields in the Force Model group affects the availability of other fields. For example, if you remove all bodies from the Primary Bodies list, the Gravity Field, Atmosphere Model, and Magnetic Field groups are disabled. Similarly, in the Gravity Field group, the search button and the Model File field are only active if “Other” is selected in the **Type** pull-down. In the Atmosphere Model group, the **SetUp** button is only active when **MSISE-90** or **Jachhia-Roberts** are selected in the **Type** pull-down

GMAT allows you to define Solar flux properties if you select either the **MSISE-90** or **Jachhia-Roberts** atmosphere models. By selecting one of these models in the **Type** pull-down menu in the Atmosphere Model group, the **Setup** button is enabled. Clicking on the **Setup** button brings up the panel illustrated in Fig. 1.6. Here you can input Solar flux values. GMAT does not currently support flux files though future versions will.

Table 2.7 contains a detailed discussion of each user-settable fields for a force model.

1.0.10 Fields Associated with a ForceModel

Table 1.4: Fields Associated with a Force Model

| Field | Options and Description |
|--------------------|--|
| CentralBody | Default: Earth . Options: [Sun , Mercury , Venus , Earth , Luna , Mars , Jupiter , Saturn , Uranus , Neptune , Pluto]: The CentralBody field allows the user to select the origin for the propagation. All propagation occurs in the FK5 axes system, about the CentralBody chosen by the user. The CentralBody must be a gravitational body and so cannot be a LibrationPoint or other special point. Units: N/A. |

Table 1.4: (Fields Associated with a Force Model...continued)

| Field | Options and Description |
|--|--|
| PrimaryBodies | Default: {Earth}. Options: [Sun, Mercury, Venus, Earth, Luna, Mars, Jupiter, Saturn, Uranus, Neptune, Pluto]: The PrimaryBodies field is a list of all celestial bodies that are to be modelled with a force model more complex than point mass gravity. Lists are surrounded by curly braces. For each PrimaryBody, the user can choose a drag, magnetic field, and aspherical gravity model. There is a coupling between the PrimaryBodies field and the PointMasses field. A primary body can be any planet or moon not included in the PointMasses field. Units: N/A. |
| Gravity.PrimaryBody.PotentialFile | Default: JGM2. Options: [CentralBody-based models, Other. See Comments]. This field allows the user to define the source for the non-spherical gravity coefficients for a primary body. If a gravity file is located in the Primary Body's potential path as defined in the startup file, you only need to specify the model name and not the entire path. For example, if the JGM2 coefficients file is contained in the directory defined in the startup file by the line EARTH.POT.PATH, then you only need to specify the model name JGM2. If the model is not contained in the body's potential path, you must supply the entire path as well as the file name. If GMAT does not successfully find the file requested, it uses the default gravity model as defined in the startup file. From the GUI, only models for Earth appear if Earth is the active primary body. This is to avoid allowing the user to select a lunar potential model for the Earth. If the Other option is selected the user has the ability of selecting a gravity model file on their local computer. Units: None. |
| Gravity.PrimaryBody.Degree | Default: 4. Options: [Integer ≥ 0 and $<$ the maximum specified by the model, Order \leq Degree]. This field allows the user to select the the degree, or number of zonal terms, in the non-spherical gravity model. Ex. Gravity.Earth.Degree = 2 tells GMAT to use only the J2 zonal term for the Earth. The value for Degree must be less than the maximum degree specified by the Model. Units: None. |
| Gravity.PrimaryBody.Order | Default: 4. Options: [Integer ≥ 0 and $<$ the maximum specified by the model, Order \leq Degree]. This field allows the user to select the the order, or number of tesseral terms, in the non-spherical gravity model. Ex. Gravity.Earth.Order = 2 tells GMAT to use 2 tesseral terms. Note: Order must be greater than or equal to Degree. Units: None. |
| Drag | Default: None. Options: [None, JachhiaRoberts, MSISE90, Exponential]. The Drag field allows a user to specify a drag model. Currently, only one drag model can be chosen for a particular propagator and only Earth models are available. Units: N/A. <i>Note: This field will be deprecated in future versions of GMAT. Currently, the Drag field and the Drag.AtmosphereModel field must be set to the same value.</i> |

Table 1.4: (Fields Associated with a Force Model...continued)

| Field | Options and Description |
|-----------------------------|--|
| Drag.AtmosphereModel | Default: None. Options: [JachhiaRoberts , MSISE90 , Exponential]. The Drag.AtmosphereModel field allows a user to specify a drag model. Currently, only one drag model can be chosen for a particular propagator and only Earth models are available. Units: N/A. |
| Drag.F107 | Default: 150. Options: [Real Number ≥ 0]. The F107 field allows you to set the $F_{10.7}$ solar flux value used in computing atmospheric density. $F_{10.7}$ is the solar radiation at a wavelength of 10.7 cm. Units: $W/m^2/Hz$ |
| Drag.F107A | Default: 150. Options: [Real Number ≥ 0]. The F107A field allows you to set the average $F_{10.7}$ value. $\bar{F}_{10.7}$ is the average of $F_{10.7}$ over one month. Units: $W/m^2/Hz$ |
| Drag.MagneticIndex | Default: 3. Options: [$0 \leq$ Real Number ≤ 9]: The MagneticIndex index field allows you to set the k_p value for use in atmospheric density calculations. k_p is a planetary 3-hour-average, geomagnetic index that measures magnetic effects of solar radiation. Units: None. |
| SRP | Default: Off . Options: [On , Off]. The SRP field allows the user to include the force due to solar radiation pressure in the total sum of forces. Units: N/A. |
| PointMasses | Default: None. Options [Sun , Mercury , Venus , Earth , Luna , Mars , Jupiter , Saturn , Uranus , Neptune , Pluto]. A PointMass is a planet or moon that is modelled by a point source located at its center of gravity. A PointMass body can be any planet or moon not included in the PrimaryBodies field. Units: N/A. |
| ErrorControl | Default: RSSStep . Options: [RSSStep , RSSState , LargestState , LargestStep]: The ErrorControl field allows you to choose how a Propagator measures the error in an integration step. The algorithm selected in the ErrorControl field is used to determine the error in the current step, and this error is compared to the value set in the Accuracy field to determine if the step has an acceptable error or needs to be improved. All error measurements are relative error, however, the reference for the relative error changes depending upon the selection of ErrorControl . RSSState is the Root Sum Square (RSS) relative error measured with respect to the current step. RSSStep is the (RSS) relative error measured with respect to the current state. LargestStep is the state vector component with the largest relative error measured with respect to the current step. LargestState is the state vector component with the largest relative error measured with respect to the current state. For a more detailed discussion see the GMAT Mathematical Specification. Units: N/A. |

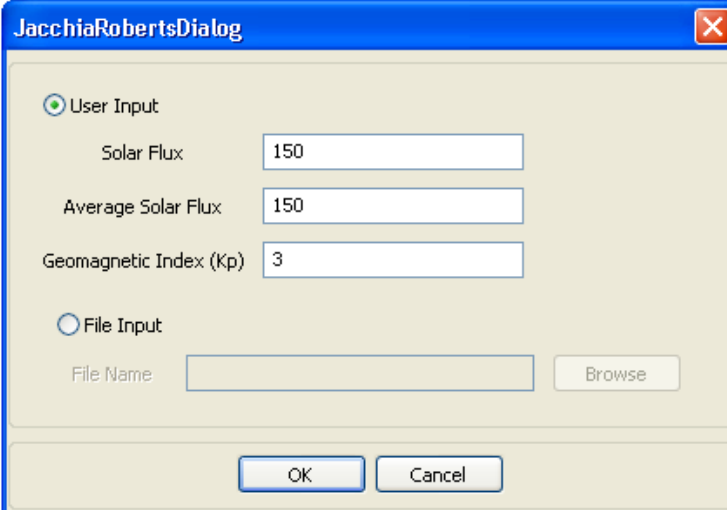
1.0.11 Fields Associated with an Integrator

Table 1.5: Fields Associated with an Integrator

| Field | Options and Description |
|---|--|
| Fields associated with All Integrators | |
| Type | Default: <code>RungeKutta89</code> . Options: [<code>RungeKutta89</code> , <code>RungeKutta68</code> , <code>RungeKutta56</code> , <code>PrinceDormand45</code> , <code>PrinceDormand78</code> , <code>BulirschStoer</code> , <code>AdamsBashforthMoulton</code>]. The Type field is used to set the type of numerical integrator. Units: N/A. |
| InitialStepSize | Default: 60 (sec). Options: [Real Number]. The InitialStepSize is the size of the first attempted step by the integrator. If the step defined by InitialStepSize does not satisfy Accuracy , the integrator adapts the step according an algorithm defined in the mathematical specifications document to find an acceptable first step that meets the user's requested Accuracy . Units: sec. |
| Accuracy | Default: 1e-11. Options: [Real Number ≥ 0]. The Accuracy field is used to set the desired accuracy for an integration step. Units: N/A. When you set a value for Accuracy , GMAT uses the method selected in ErrorControl field on the Force Model, to determine a metric of the accuracy. For each step, the integrator ensures that the accuracy, as calculate using the method define by ErrorControl , is less than the limit defined by Accuracy . If an integrator exceeds MaxStepAttempts trying to meet the requested accuracy, and error message is thrown and propagation stops. |
| MinStep | Default: .001 (sec). Options: [Real Number > 0 , $\text{MinStep} \leq \text{MaxStep}$]. The MinStep field is used to set the minimum allowable step size. Units: sec. |
| MaxStep | Default: 2700.0 (sec.). Options: [Real Number > 0 , $\text{MinStep} \leq \text{MaxStep}$]. The MaxStep field is used to set the maximum allowable step size. Units: sec. |
| MaxStepAttempts | Default: 50. Options: [Integer > 0]. The MaxStepAttempts field allows the user to set the number of attempts the integrator takes to meet the tolerance defined by Accuracy . Units: None. |
| Fields associated only with Adams-Bashforth-Moulton Integrator | |
| MinIntegrationError | Default: 1.0e-13. Options: [Real Number > 0 , $\text{MinIntegrationError} < \text{NomIntegrationError} < \text{Accuracy}$]: The MinIntegrationError field is used by the ABM integrator (and other predictor-corrector integrators when implemented) as the desired integration error to be obtained when the step size is changed. Predictor-Corrector integrators adapt step size when the obtained integration error falls outside of the range of acceptable steps, as determined by the bounds set by the MinIntegrationError and Accuracy fields. The integrator then applies an internal calculation to recompute the step size, attempting to hit the NomIntegrationError , and restarts the integrator. Units: N/A. |

Table 1.5: Fields Associated with an Integrator....(continued)

| Field | Options and Description |
|---|---|
| NomIntegrationError | Default: 1.0e-11. Options: [Real Number > 0, MinIntegrationError < NomIntegrationError < Accuracy]: The NomIntegrationError field is used by the ABM integrator (and other predictor-corrector integrators when implemented) as the desired integration error to be obtained when the step size is changed. Predictor-Corrector integrators adapt step size when the obtained integration error falls outside of the range of acceptable steps, as determined by the bounds set by the MinIntegrationError and Accuracy fields. The integrator then applies an internal calculation to recompute the step size, attempting to hit the NomIntegrationError, and restarts the integrator. Units: N/A. |
| Script Examples | |
| <pre> Create ForceModel MyProp_ForceModel; GMAT MyProp_ForceModel.CentralBody = Earth; GMAT MyProp_ForceModel.PrimaryBodies = {Earth}; GMAT MyProp_ForceModel.PointMasses = {Sun, Luna}; GMAT MyProp_ForceModel.Drag = None; GMAT MyProp_ForceModel.SRP = Off; GMAT MyProp_ForceModel.ErrorControl = RSSStep; GMAT MyProp_ForceModel.Gravity.Earth.Degree = 4; GMAT MyProp_ForceModel.Gravity.Earth.Order = 4; GMAT MyProp_ForceModel.Gravity.Earth.PotentialFile =/JGM2v; Create Propagator MyProp; GMAT MyProp.FM = MyProp_ForceModel; GMAT MyProp.Type = RungeKutta89; GMAT MyProp.InitialStepSize = 60; GMAT MyProp.Accuracy = 9.999999999999999e-012; GMAT MyProp.MinStep = 0.001; GMAT MyProp.MaxStep = 2700; GMAT MyProp.MaxStepAttempts = 50; </pre> | |



The image shows a Windows-style dialog box titled "JacchiaRobertsDialog". It has a blue title bar with a close button (X) in the top right corner. The main area is light beige and contains two radio button options: "User Input" (selected) and "File Input". Under "User Input", there are three text input fields: "Solar Flux" with the value "150", "Average Solar Flux" with the value "150", and "Geomagnetic Index (Kp)" with the value "3". Under "File Input", there is a "File Name" text input field and a "Browse" button. At the bottom of the dialog are "OK" and "Cancel" buttons.

| Option | Parameter | Value |
|-----------------------|------------------------|--------|
| User Input (Selected) | Solar Flux | 150 |
| | Average Solar Flux | 150 |
| | Geomagnetic Index (Kp) | 3 |
| File Input | File Name | |
| | Browse | Button |

Figure 1.6: Drag Setup Dialogue Box

Chapter 2

Object Fields: Quick Look-up Tables

2.1 Spacecraft and Hardware Fields

| Spacecraft Dialogue Box / Orbit Tab | | |
|-------------------------------------|-----------------|------|
| Epoch Format | TAI Mod Julian | |
| Epoch | 21545.000000000 | |
| Coordinate System | Earth MJ2000 Eq | |
| State Type | Cartesian | |
| Elements | | |
| X | 7100 | km |
| Y | 0 | km |
| Z | 1300 | km |
| VX | 0 | km/s |
| VY | 7.35 | km/s |
| VZ | 1 | km/s |

Figure 2.1: Spacecraft Dialogue Box / Orbit Tab

2.1.1 Overview of the Spacecraft Object

The Spacecraft object is one of the most important resources in GMAT and can be configured in numerous ways. For most mission applications, GMAT's primary use and function is to simulate and model how an actual spacecraft would behave (or behaved) in a flight situation. You do this by creating and configuring spacecraft objects, GMAT's mathematical model of real-world spacecraft, and by issuing commands such as **Propagate** for GMAT to apply to the spacecraft model.

The types of parameters and settings on the Spacecraft Object fall into several categories: Orbit, Attitude,

Ballistic/Mass, Sensors, Tanks, and Actuators. Each of these is configured on a separate tab on the Spacecraft dialog box. For example, you can configure the initial state and epoch on the Orbit tab, and the , the mass and ballistic properties on the Ballistic/Mass tab. In the following sections we discuss each tab in detail.

Possible Coupling with Other Objects

A Spacecraft Requires Other Objects/Commands of Type: None.

A Spacecraft has the Potential to Couple with Objects/Commands of Type: Tank, Thruster, Differential Corrector, fminconOptimizer, XYPlot, OpenGLPlot, ReportFile, Variables/Arrays, Coordinate System, MATLAB Function, BeginFiniteBurn, EndFiniteBurn, Function Call, Assignment Command, Maneuver, Propagate, Report, Save, Script Event, If, For, While, Vary, Achieve, Minimize, NonlinearConstraint.

2.1.2 Spacecraft Orbit Tab

The Spacecraft/Orbit tab is used to set the orbit state and epoch and is illustrated in Fig. 2.1. On this tab, you can choose the epoch, coordinate system, and the state representation in which to enter initial condition information. There are three groups on the Spacecraft/Orbit tab: Epoch, State Configuration, and State Vector. Below, we discuss each group in detail.

Epoch Group

The Epoch group allows you to select the time system and time format in which to enter the initial Spacecraft epoch. Several choices are available including `A1ModJulian`, `TA1ModJulian`, `UTCModJulian`, `TTModJulian`, `A1Gregorian`, `TA1Gregorian`, `UTCGregorian`, `TTGregorian`. An epoch can be provided in either the Modified Julian Date (with reference epoch 05 Jan 1941 12:00:00.000 TAI) or Gregorian Date formats. As an example, the J2000 Epoch should be expressed using the Gregorian date format as 01 Jan 2000 12:00.000 (TDB).

Note that if you change the `EpochFormat` combo box, and have defined the spacecraft state with respect to a time dependent coordinate system, the state vector representation in the GUI does *not* change. For example, if you define a Spacecraft's state with respect to the Earth Fixed system, and then change the epoch, you have not changed the state vector in the Earth Fixed system and therefore the values in the GUI do not change. However, change the epoch does change the inertial state that results from converting the Earth Fixed state to the inertial state. This is because the orientation of the Earth Fixed frame is different at the new epoch, and so the transformation to the inertial frame yields a new results.

State Configuration Group

The State Configuration group allows the user to select the coordinate system and state representation for a Spacecraft's initial conditions. The `StateType` pull-down menu contains several options for the orbit state Representation including `Cartesian`, `Keplerian`, `ModifiedKeplerian`, `SphericalAZFPA`, `SphericalRADEC`, `Equinoctial`. The `Coordinate System` pull-down menu allows you to specify the Coordinate System in which the Spacecraft's initial conditions are expressed. The default coordinate systems always appear and are `EarthMJ2000Eq`, `EarthMJ000Ec`, and `EarthFixed`. If you create other user defined Coordinate Systems, they also appear in the `Coordinate System` drop-down menu. The numeric values contained in the State Vector group are dynamically updated as changes are made to `State Type` and `Coordinate System`. For example, if you enter a state vector in `EarthMJ2000Eq`, hit apply, and change the `Coordinate System` pull-down to `Earth Fixed`, the GUI will reconfigure to show the equivalent state vector in the Earth Fixed system at the defined epoch.

State Vector Group

The State Vector group contains the numeric values for a Spacecraft's initial conditions. The state vector is shown in the selected state representation as defined in `State Type` and is expressed in the requested coordinate system defined by `Coordinate System`. The labels, units, and numeric values dynamically respond to changes in either the `Coordinate System` or `State Type` pull-down menus. You can use the State Vector to group to define a spacecraft's initial conditions in any coordinate system, or to view the spacecraft's state in any coordinate system.

2.1. SPACECRAFT AND HARDWARE FIELDS

A detailed discussion of all fields on the Spacecraft Orbit tab is found in Table 2.1. Now let's look at the Spacecraft Attitude tab.

2.1.3 Spacecraft Attitude Tab

This Tab is not currently supported in GMAT. It is included only to illustrate look-and-feel of future enhancements.

2.1.4 Spacecraft Ballistic/Mass Tab

The Ballistic/Mass tab, shown in Fig. 2.2 is used to set spacecraft mass and ballistic properties. On this panel, you can set properties such as `DryMass`, `DragArea`, and `SRPArea` among others. GMAT currently only supports a point-mass spacecraft model. In the future GMAT will support a higher fidelity spacecraft model, and this panel will allow you to set the spacecraft moments of inertia and other properties.

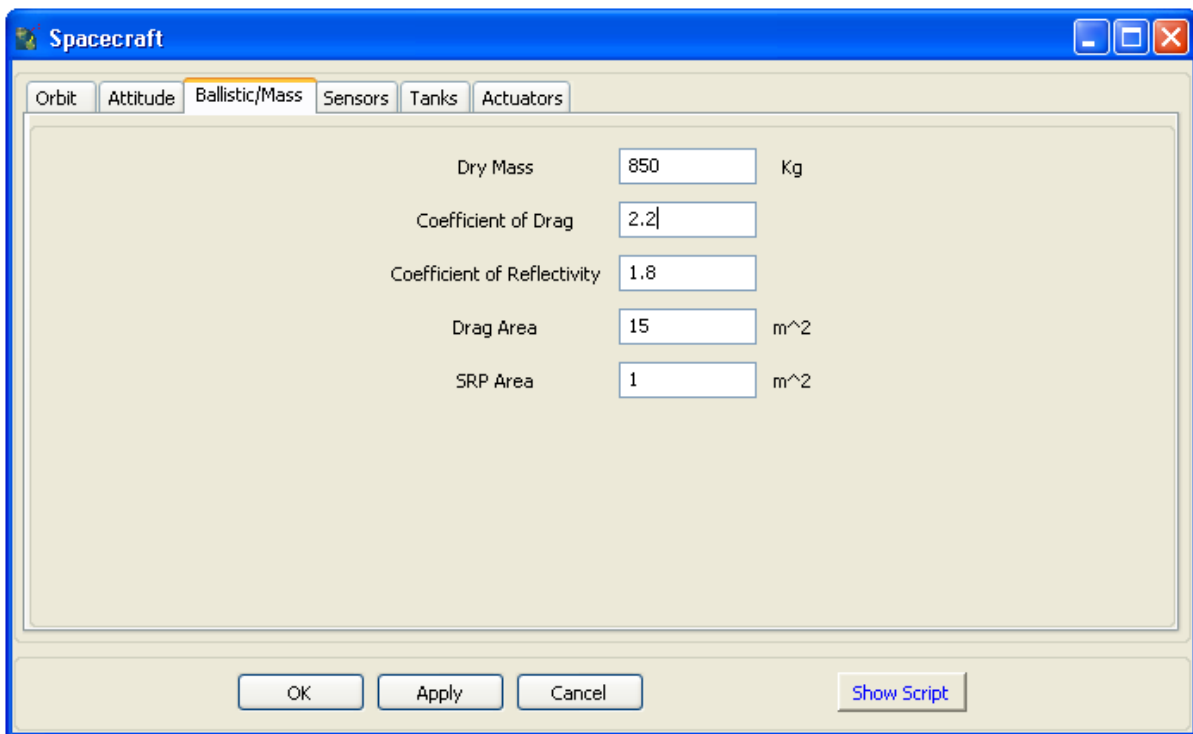


Figure 2.2: Spacecraft Dialogue Box / Ballistic/Mass Tab

Ballistics Group

The Ballistics group allows the user to specify spacecraft physical properties that are used to calculate properties such as the ballistic coefficient. A detailed discussion of all fields on the Spacecraft Ballistic/Mass tab is found in Table 2.3. Now let's look at the Sensors tab.

2.1.5 Spacecraft Sensors Tab

This Tab is not currently supported in GMAT.

2.1.6 Spacecraft Tanks Tab

The Spacecraft/Tanks tab allows you to add multiple tanks to a spacecraft. Tanks are created separately from spacecraft and if you have not created any tanks, the Available Tanks list will appear empty. You can add an existing tank to a spacecraft by selecting the desired tank using a left mouse click and then using a left mouse click on the right-arrow icon. If there are no existing tanks, go to the resource tree, right click on the Hardware folder that appears as a subfolder to spacecraft, and select Add/Fuel Tank.

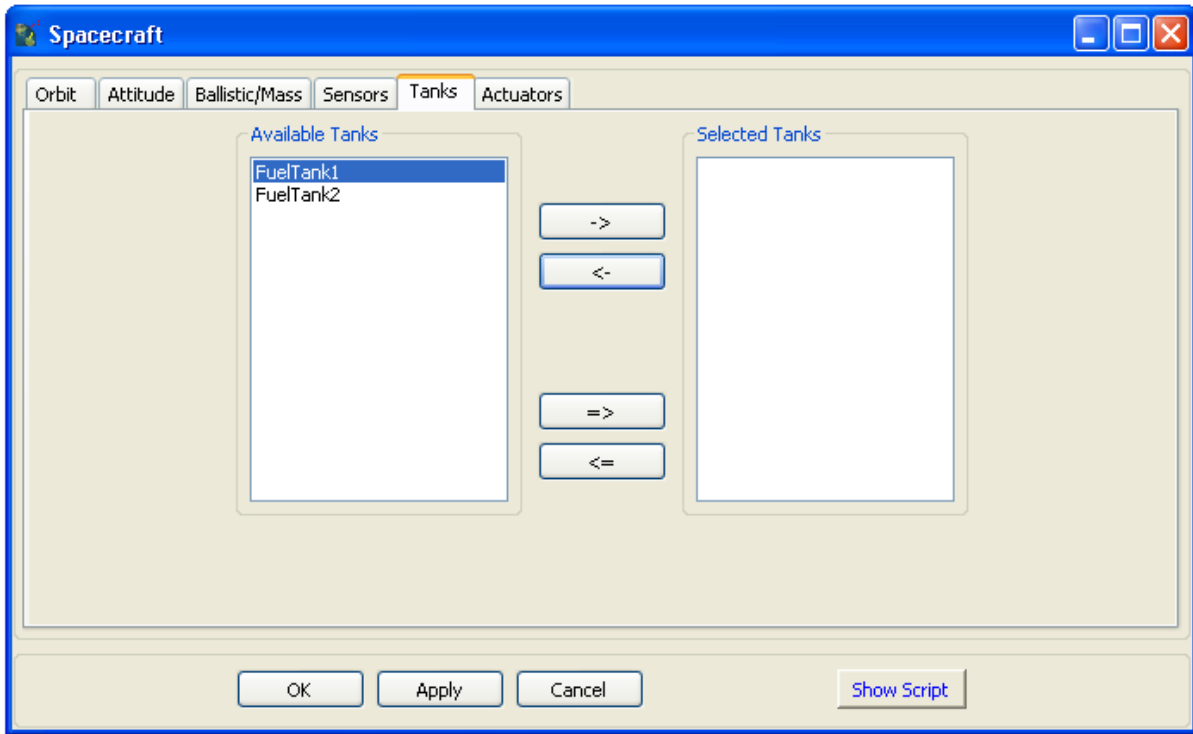


Figure 2.3: Spacecraft Dialogue Box / Tanks Tab

2.1.7 Spacecraft Actuators Tab

The spacecraft/Actuators tab allows you to add multiple actuators to a spacecraft. Currently the only actuator that GMAT supports are thrusters. You must create a thruster before you can add it to a spacecraft. If you have not created any thrusters, the Available Thrusters list will appear empty. You can add existing thrusters to a spacecraft by selecting the desired thruster using a left mouse click and then using a left mouse click on the right-arrow icon. To create a Thruster, go to the resource tree, right click on the Hardware folder that appears as a subfolder to spacecraft, and select Add/Thruster.

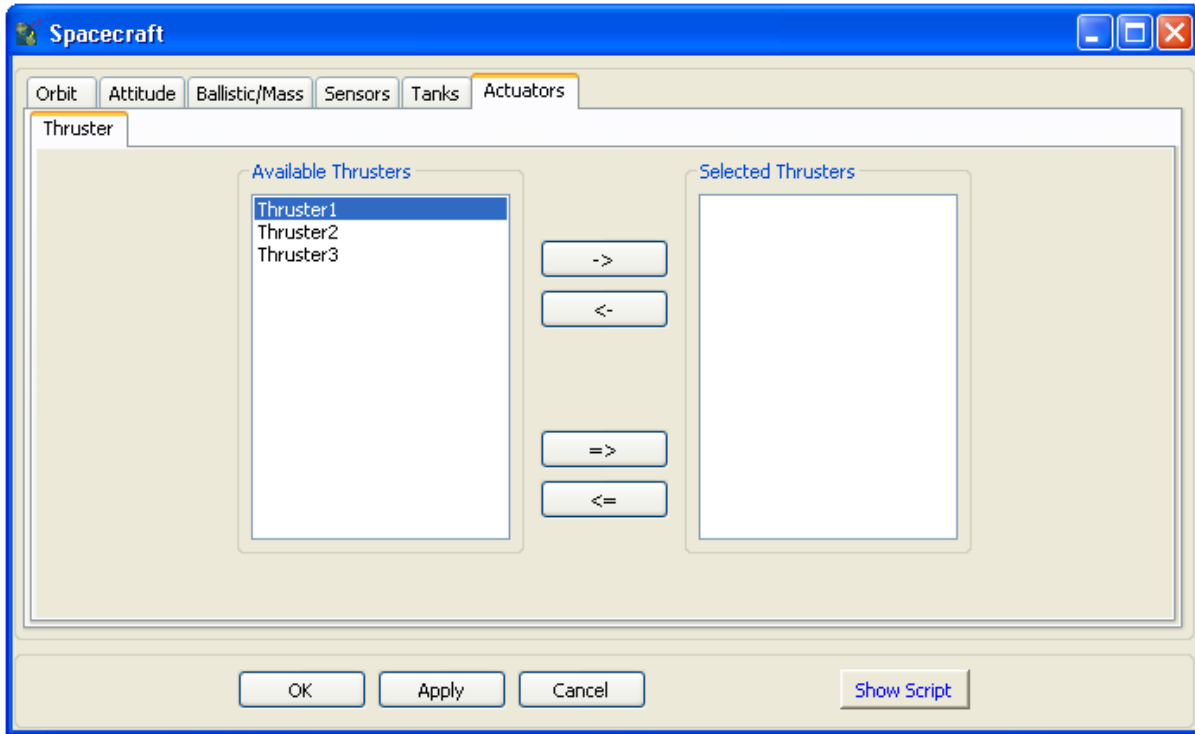


Figure 2.4: Spacecraft Dialogue Box / Actuators Tab

Table 2.1: Fields Associated with a Spacecraft Orbit State
(Orbit Tab)

| Field | Options and Description |
|-------------------|--|
| StateType | Default: Cartesian. Options: [Cartesian, Keplerian, ModifiedKeplerian, SphericalAZFPA, SphericalRADEC, Equinoctial]. The StateType field allows the user to configure the type of state vector that they wish to use. The Statetype field has a dependency upon the CoordinateSystem field. If the Coordinate System chosen by the user does not have a gravitational body at the origin, then the state types Keplerian, ModifiedKeplerian, and Equinoctial are not permitted. This is because these state types require a μ value. Units: N/A. When the Keplerian or ModifiedKeplerian state types are selected, the Anomaly Type field becomes visible. |
| Coordinate System | Default: EarthMJ2000Eq. Options: [EarthMJ2000Eq, EarthMJ2000Ec, EarthFixed, or any user defined system]: The Coordinate System field allows the user to choose which coordinate system with which to define the orbit state vector. The CoordinateSystem field has a dependency upon the StateType field. If the Coordinate System chosen by the user does not have a gravitational body at the origin, then the state types Keplerian, ModifiedKeplerian, and Equinoctial are not permitted. This is because these state types require a μ value. Units: N/A. |

Table 2.1: (Fields Associated with a Spacecraft Orbit State (Orbit Tab). continued)

| Field | Options and Description |
|-------------|--|
| EpochFormat | Default: TAIModJulian. Options: [A1ModJulian, TAIModJulian, UTCModJulian, TTModJulian, A1Gregorian, TAIGregorian, UTCTGregorian, TTGregorian]: The DateFormat field allows the user to specify the format for defining a spacecraft's initial epoch. DateFormat determines both the time system (TAI, TT, etc) and the time format (MJD or Gregorian). Units: N/A. |
| Epoch | Default: 21545.000000000. Options: [See Comments]: The Epoch field allows the user to specify the initial spacecraft epoch. The format of the epoch must be consistent with the DateFormat field. If DateFormat is of the "MJD" type, then the epoch is in Modified Julian format. If DateFormat is a "Gregorian Type", the format is similar to 01 Jan 2000 12:00:00.000. Units: MJD - days, Gregorian - N/A. |
| AnomalyType | Default: TA. Options: [TA, MA, EA, HA]: The Epoch field allows the user to specify the to select the AnomalyType needed for the Keplerian or ModifiedKeplerian spacecraft state. In the scripting environment, AnomalyType is not used. Units: N/A. |

Fields associated with Cartesian state.

| | |
|----|--|
| X | Default: 7100. Options: [Real Number]: X is the x-component of the Spacecraft state in the coordinate system chosen in the Spacecraft CoordinateSystem field. Units: km. |
| Y | Default: 0. Options: [Real Number]: Y is the y-component of the Spacecraft state in the coordinate system chosen in the Spacecraft CoordinateSystem field. Units: km. |
| Z | Default: 1300. Options: [Real Number]: Z is the z-component of the Spacecraft state in the coordinate system chosen in the Spacecraft CoordinateSystem field. Units: km. |
| VX | Default: 0. Options: [Real Number]: VX is the x-component of the Spacecraft velocity in the coordinate system chosen in the Spacecraft CoordinateSystem field. Units: km/sec. |
| VY | Default: 7.35. Options: [Real Number]: VY is the y-component of the Spacecraft velocity in the coordinate system chosen in the Spacecraft CoordinateSystem field. Units: km/sec. |
| VZ | Default: 1.0. Options: [Real Number]: VZ is the z-component of the Spacecraft velocity in the coordinate system chosen in the Spacecraft CoordinateSystem field. Units: km/sec. |

NOTE: Default values for the remaining state types are obtained through transformations of the default Cartesian spacecraft state values. The Keplerian, ModifiedKeplerian, and Equinoctial are dependant on the origin of the CoordinateSystem, because the state types require a μ value.

Table 2.1: (Fields Associated with a Spacecraft Orbit State (Orbit Tab). continued)

| Field | Options and Description |
|---|--|
| Fields associated with Keplerian state. | |
| SMA | Default: 7191.938817629. Options: [Real Number $\neq 0$]: The SMA field is the spacecraft orbit's osculating Keplerian semimajor axis in coordinate system chosen in the Spacecraft CoordinateSystem field. SMA must be strictly greater than or less than zero. For circular and elliptical ($0 \leq \text{ECC} < 1$) orbits SMA should only be a positive Real Number and for hyperbolic orbits ($\text{ECC} > 1$) SMA should only be a negative Real Number. GMAT does not support the creation of parabolic orbits. Units: km. |
| ECC | Default: 0.024549749. Options: [$0 \leq$ Real Number, $\text{ECC} \neq 1$]: The ECC field is the spacecraft orbit's osculating eccentricity. ECC must be greater than or equal to zero but not equal to one (GMAT does not support parabolic orbits). Note: ECC can be greater than one. See the SMA description for additional restrictions to the allowable values of ECC. Units: Dimensionless. |
| INC | Default: 12.850080057. Options: [Real Number]: The INC field is the spacecraft orbit's osculating inclination, in degrees, w/r/t to the selected coordinate system. Units: degrees. |
| AOP | Default: 314.190551536. Options: [Real Number]: The AOP field is the spacecraft orbit's osculating argument of periapsis, in degrees, w/r/t to the selected coordinate system. Units: degrees. |
| RAAN | Default: 306.614802195. Options: [Real Number]: The RAAN field is the spacecraft orbit's osculating right ascension of the ascending node, in degrees, w/r/t to the selected coordinate system. Units: degrees. |
| TA | Default: 99.887749332. Options: [Real Number]: The TA field is the spacecraft orbit's osculating true anomaly. Units: degrees. |
| MA | Default: 97.107826639. Options: [Real Number]: The MA field is the spacecraft orbit's osculating mean anomaly. Units: degrees. |
| EA | Default: 98.498977103. Options: [Real Number]: The EA field is the spacecraft orbit's osculating eccentric anomaly. Units: degrees. |
| HA | Default: 0.000000000. Options: [Real Number]: The HA field is the spacecraft orbit's osculating hyperbolic anomaly. Units: degrees. |
| Fields associated with Modified Keplerian state. | |
| RadApo | Default: 7015.378524789. Options: [Real Number $\neq 0$]: The RadApo field is the spacecraft orbit's osculating radius of apoapsis. RadApo must be strictly greater than or less than zero. When RadApo is negative, the orbit is hyperbolic. Units: km. |

Table 2.1: (Fields Associated with a Spacecraft Orbit State (Orbit Tab). continued)

| Field | Options and Description |
|--------|--|
| RadPer | Default: 7368.4991104681 Options: [Real Number > 0]: The RadPer field is the spacecraft orbit's osculating radius of periapsis. RadPer must be greater than zero. Units: km. |
| INC | See the Keplerian state section for a description on this field. |
| AOP | See the Keplerian state section for a description on this field. |
| RAAN | See the Keplerian state section for a description on this field. |
| TA | See the Keplerian state section for a description on this field. |
| MA | See the Keplerian state section for a description on this field. |
| EA | See the Keplerian state section for a description on this field. |
| HA | See the Keplerian state section for a description on this field. |

Fields associated with SphericalAZFPA state.

| | |
|------|---|
| RMAG | Default: 7218.03297304. Options: [Real Number > 0]: The RMAG field allows the user to set the magnitude of the spacecrafts position vector. Units: km. |
| RA | Default: 0. Options: [Real Number]: The RA field allows the user to set the spacecraft's right ascension. Units: degrees. |
| DEC | Default: 10.3758449200. Options: [Real Number]: The DEC field allows the user to set the spacecraft's declination. Units: degrees. |
| VMAG | Default: 7.41771528167. Options: [Real Number \geq 0]: The VMAG field allows the user to set the magnitude of the spacecraft's velocity. Units: km/sec. |
| AZI | Default: 82.377421681. Options: [Real Number]: The AZI field allows the user to set the spacecraft's azimuth angle. Units: degrees. |
| FPA | Default: 88.60870365370. Options: [Real Number]: The FPA allows the user to set a spacecraft's flight path angle. Units: degrees. |

Fields associated with SphericalRADEC state.

| | |
|------|--|
| RMAG | See the SphericalAZFPA state section for a description on this field. |
| RA | See the SphericalAZFPA state section for a description on this field. |
| DEC | See the SphericalAZFPA state section for a description on this field. |
| VMAG | See the SphericalAZFPA state section for a description on this field. |

Table 2.1: (Fields Associated with a Spacecraft Orbit State (Orbit Tab). continued)

| Field | Options and Description |
|---|--|
| RAV | Default: 90. Options: [Real Number]: The RAV field allows the user to set the right ascension of the spacecraft's velocity. Units: degrees. |
| DECV | Default: 7.7477720361. Options: [Real Number]: The DECV field allows the user to set the declination of the spacecraft's velocity. Units: degrees. |
| Fields associated with Equinoctial elements. | |
| SMA | See the Keplerian state section for a description on this field. |
| h | Default: -0.024234314. Options: [Real Number]: The h field is the projection of the eccentricity vector onto the y_{ep} axes. The \mathcal{F}_{ep} system is a system used in calculating the equinoctial elements and is beyond the scope of this discussion. The GMAT Mathematical Specifications document discusses \mathcal{F}_{ep} and the calculation of the equinoctial elements in detail. Units: None. |
| k | Default: -0.003922779. Options: [Real Number]: The k field is the projection of the eccentricity vector onto the x_{ep} axes. The \mathcal{F}_{ep} system is a system used in calculating the equinoctial elements and is beyond the scope of this discussion. The GMAT Mathematical Specifications document discusses \mathcal{F}_{ep} and the calculation of the equinoctial elements in detail. Units: None. |
| p | Default: -0.090388347. Options: [Real Number]: The p field is the projection of the N vector onto the y_{ep} axes. The N vector and the \mathcal{F}_{ep} system are used in calculating the equinoctial elements and are beyond the scope of this discussion. The GMAT Mathematical Specifications document discusses N and \mathcal{F}_{ep} and the calculation of the equinoctial elements in detail. Units: None. |
| q | Default: 0.067164549. Options: [Real Number]: The q field is the projection of the N vector onto the x_{ep} axes. The N vector and the \mathcal{F}_{ep} system are used in calculating the equinoctial elements and are beyond the scope of this discussion. The GMAT Mathematical Specifications document discusses N and \mathcal{F}_{ep} and the calculation of the equinoctial elements in detail. Units: None. |
| MeanLongitude | Default: 3.16359946. Options: [Real Number]: The MeanLongitude field is the the spacecraft's mean longitude. The GMAT Mathematical Specifications document discusses mean longitude and the calculation of the equinoctial elements in detail. Units: degrees. |

Table 2.2: Fields Associated with Spacecraft Physical Properties
(Ballistic/Mass Tab)

| Field | Options and Description |
|-----------------|--|
| DryMass | Default: 850. Options: [Real Number ≥ 0]: The DryMass field allows the user to specify the mass of the spacecraft structure, but does not include the mass of tanks, thrusters, or fuel. Units: kg. |
| Cd | Default: 2.2. Options: [Real Number ≥ 0]: The Cd field allows the user to specify the spacecraft's drag coefficient. Units: None. |
| Cr | Default: 1.8. Options: [Real Number ≥ 0]: The Cr field allows the user to specify the spacecraft's coefficient of reflectivity. Units: None. |
| DragArea | Default: 15. Options: [Real Number ≥ 0]: The DragArea is the effective spacecraft area used in calculate the force due to drag. Units: m^2 . |
| SRPArea | Default: 1. Options: [Real Number ≥ 0]: The SRPArea is the effective spacecraft area used in calculate the force due to solar radiation pressures. Units: m^2 . |

Table 2.3: Fields Associated with a Spacecraft Ballistic and Mass Properties

| Field | Options and Description |
|-----------------|--|
| Cd | Default: 2.2. Options: [Real Number > 0]: Cd is the spacecraft's drag coefficient. Cd must be greater than 0. Units: Dimensionless. |
| Cr | Default: 2.2. Options: [$0 \leq$ Real Number ≤ 2.0]: Cr is the spacecraft's coefficient of reflectivity. Cr must be greater than 0. Units: Dimensionless. |
| DragArea | Default: 15.0. Options: [Real Number > 0]: The DragArea is the area of the spacecraft that is used in calculating atmospheric drag. DragArea must be greater than 0. Units: m^2 |
| SRPArea | Default: 1.0. Options: [Real Number > 0]: The SRPArea is the area of the spacecraft that is used in calculating the force due to solar radiation pressure. SRPArea must be greater than 0. Units: m^2 |
| DryMass | Default: 850.0. Options: [Real Number > 0]: The DryMass is the mass of the spacecraft without the mass of tanks and fuel. DryMass must be greater than 0. Units: kg |

Table 2.4: Fields Associated with Spacecraft Attitude State
(Attitude Tab)

| Field | Options and Description |
|-----------------------------------|--|
| Attitude Mode | Default: <code>CSFixed</code> . Options:[<code>CSFixed</code> , <code>Spinner</code>]: The <code>AttitudeMode</code> mode field allows the user to specify the attitude dynamics model to be used by GMAT to propagate a spacecraft's attitude. The attitude dynamics model uses the initial attitude state and the algorithm associated with <code>AttitudeMode</code> to advance the attitude state in time. Units: N/A. |
| Attitude Coordinate System | Default: <code>EarthMJ2000Eq</code> . Options: [<code>EarthMJ2000Eq</code> , <code>EarthMJ2000Ec</code> , <code>EarthMJ2000Eq</code> , or any user defined system]: A spacecraft's initial body axes orientation as defined by the quaternions or some other parameterizations are expressed with respect to the <code>AttitudeCoordinateSystem</code> . Unlike an orbit state, an attitude state is really information that uniquely defines a rotation matrix. A spacecraft's attitude is the orientation of the spacecraft's body-fixed frame with respect to the inertial frame. However, it is often more convenient to define the initial attitude with respect to an intermediate frame than with respect to an inertial frame. The <code>Attitude CoordinateSystem</code> allows the user to define the initial orientation of a spacecraft's body axes, with respect to any frame GMAT knows how to calculate. Units: N/A. |
| Attitude StateType | Default: <code>EulerAngles</code> . Options:[<code>EulerAngles</code> , <code>Quaternions</code> , <code>DCM</code>]: The <code>AttitudeStateType</code> field allows the user to choose among different attitude parameterizations when defining the attitude initial conditions. Units: N/A. |
| Attitude Rate StateType | Default: <code>EulerAngleRates</code> . Options:[<code>EulerAngleRates</code> , <code>AngularVelocity</code>]: The <code>AttitudeRateStateType</code> field allows the user to define the attitude parameterization to be used in defining the initial attitude rate. Units: N/A. |
| Euler Angle Sequence | Default: 312. Options:[123, 132, 121, 131, 213, 231, 212, 232, 312, 321, 313, 323]: The <code>EulerAngleSequence</code> field allows the user to define the Euler sequence used in rotating from the body-fixed to the inertial axes. For example, if <code>EulerAngleSequence</code> is selected as 321, then the first rotation is a 3 rotation through <code>EulerAngle1</code> , the second rotation is a 2 rotation through <code>EulerAngle2</code> , and the third rotation is a 1 rotation through <code>EulerAngle3</code> . Units: N/A. |

Fields associated with Spacecraft Attitude State

| | |
|--------------------|--|
| EulerAngle1 | Default: 0. Options:[Real Number]: <code>EulerAngle1</code> is one of three Euler angles that can be used to define the initial conditions of a spacecraft. <code>EulerAngle1</code> corresponds to the first rotation performed in the sequence that goes from the spacecraft body frame to the inertial frame. For example, if the <code>EulerAngleSequence</code> field is set to 321,the first rotation from the body to the inertial frame would be a 3-rotation through <code>EulerAngle1</code> . Units: degrees. |
| EulerAngle2 | Default: 0. Options:[Real Number]: <code>EulerAngle2</code> is one of three Euler angles that can be used to define the initial conditions of a spacecraft. <code>EulerAngle2</code> corresponds to the second rotation performed in the sequence that goes from the spacecraft body frame to the inertial frame. For example, if the <code>EulerAngleSequence</code> field is set to 321,the second rotation from the body to the inertial frame would be a 2-rotation through <code>EulerAngle2</code> . Units: degrees. |
| EulerAngle3 | Default: 0. Options:[Real Number]: <code>EulerAngle3</code> is one of three Euler angles that can be used to define the initial conditions of a spacecraft. <code>EulerAngle3</code> corresponds to the third rotation performed in the sequence that goes from the spacecraft body frame to the inertial frame. For example, if the <code>EulerAngleSequence</code> field is set to 321,the third rotation from the body to the inertial frame would be a 1-rotation through <code>EulerAngle3</code> . Units: degrees. |

Table 2.4: (Fields Associated with Spacecraft Attitude State (Attitude Tab)continued)

| Field | Options and Description |
|------------------|---|
| q1 | Default: 0. Options:[Real Number]: The q1 parameter is the first element of the quaternion. GMAT normalizes the quaternion to be of length 1. Units: degrees. |
| q2 | Default: 0. Options:[Real Number]: The q2 parameter is the second element of the quaternion. GMAT normalizes the quaternion to be of length 1. Units: degrees. |
| q3 | Default: 0. Options:[Real Number]: The q3 parameter is the third element of the quaternion. GMAT normalizes the quaternion to be of length 1. Units: degrees. |
| q4 | Default: 1. Options:[Real Number]: The q4 parameter is the fourth element of the quaternion. GMAT normalizes the quaternion to be of length 1. Units: degrees. |
| DCM11 | Default: 1. Options:[Real Number]: The DCM11 parameter is the upper left component of the direction cosine matrix that rotates from the spacecraft body frame to the inertial frame. GMAT normalizes the attitude matrix to have a determinant of 1. The default DCM matrix is the identity matrix. Units: None. |
| DCM12 | Default: 0. Options:[Real Number]: The DCM12 parameter is the R_{12} component of the direction cosine matrix that rotates from the spacecraft body frame to the inertial frame. GMAT normalizes the attitude matrix to have a determinant of 1. The default DCM matrix is the identity matrix. Units: None. |
| DCM33 | Default: 1. Options:[Real Number]: The DCM33 parameter is the R_{33} component of the direction cosine matrix that rotates from the spacecraft body frame to the inertial frame. GMAT normalizes the attitude matrix to have a determinant of 1. The default DCM matrix is the identity matrix. Units: None. |
| EulerAngleRate1 | Default: 0. Options:[Real Number]: The EulerAngleRate1 defines the time-rate-of-change of EulerAngle1 , expressed in the the system defined by AttitudeCoordinateSystem . Units: deg/sec. |
| EulerAngleRate2 | Default: 0. Options:[Real Number]: The EulerAngleRate2 defines the time-rate-of-change of EulerAngle2 , expressed in the the system defined by AttitudeCoordinateSystem . Units: deg/sec. |
| EulerAngleRate3 | Default: 0. Options:[Real Number]: The EulerAngleRate3 defines the time-rate-of-change of EulerAngle3 , expressed in the the system defined by AttitudeCoordinateSystem . Units: deg/sec. |
| AngularVelocityX | Default: 0. Options:[Real Number]: The AngularVelocityX component is the x-component of the spacecraft's body axes with respect to the system defined by AttitudeCoordinateSystem . Units: deg/sec. |
| AngularVelocityY | Default: 0. Options:[Real Number]: The AngularVelocityY component is the y-component of the spacecraft's body axes with respect to the system defined by AttitudeCoordinateSystem . Units: deg/sec. |
| AngularVelocityZ | Default: 0. Options:[Real Number]: The AngularVelocityZ component is the z-component of the spacecraft's body axes with respect to the system defined by AttitudeCoordinateSystem . Units: deg/sec. |

Table 2.5: Fields Associated with a Spacecraft Tank(Tanks Tab)

| Field | Options and Description |
|--------------------------|--|
| FuelMass | Default: 756. Options: [Real Number ≥ 0]: The FuelMass field is the mass of fuel in the tank. Units: kg. |
| Pressure | Default: 1500. Options: [Real Number ≥ 0]: The Pressure field is the pressure of the fuel in the tank. Units: kPa. |
| Temperature | Default: 20. Options: [Real Number]: The Temperature field is the temperature of the fuel in the tank. Units: C. |
| RefTemperature | Default: 20. Options: [Real Number]: RefTemperature Units: C. |
| Volume | Default: 0.75. Options: [Real Number ≥ 0]: The Volume field is the volume of the tank. Units: m ³ . |
| FuelDensity | Default: 1260. Options: [Real Number ≥ 0]: The FuelDensity parameter is the fuel density. Units: kg/m ³ |
| PressureRegulated | Default: true . Options: [true false]: The PressureRegulated flag allows the user to choose between a pressure regulated tank or a blow down tank. If PressureRegulated is true, then the pressure is held constant as fuel mass is depleted. If PressureRegulated is false, then the pressure decreases as fuel is depleted. |

Table 2.6: Fields Associated with a Spacecraft Thruster
(Actuators Tab)

| Field | Options and Description |
|-------------------------|--|
| CoordinateSystem | Default: EarthMJ2000Eq. Options: [EarthMJ2000Eq, EarthMJ2000Ec, EarthMJ2000Eq, or any user defined system]: The CoordinateSystem field for a thruster determines what coordinate system the orientation parameters X_Direction , Y_Direction , and Z_Direction are referenced to. This is a temporary fix in GMAT. Eventually, the user will specify the attitude of a spacecraft, and then X_Direction , Y_Direction , and Z_Direction will be referenced to the spacecraft body frame. |
| Axis | Default: VNB. Options: [Inertial VNB]: The Axis field allows the user to define a local coordinate system for a thruster. Note that there is a coupling between the Axis parameter and the CoordinateSystem parameter for a thruster. Only one of the two can be specified. Units: N/A. |
| Origin | Default: Earth . Options: [Sun, Mercury, Venus, Earth, Luna, Mars, Jupiter, Saturn, Uranus, Neptune, Pluto]: The Origin field allows the user to define a local origin for a thruster. Note that there is a coupling between the Origin parameter and the CoordinateSystem parameter for a thruster. Only one of the two can be specified. Units: N/A. |
| X_Direction | Default: 1. Options: [Real Number]: X_Direction , divided by the RSS of the three direction components, forms the x direction of the spacecraft thrust vector direction. |

Table 2.6: Fields Associated with a Spacecraft Thruster
(Actuators Tab) (continued)

| Field | Options and Description |
|---|--|
| YDirection | Default: 0. Options: [Real Number]: YDirection , divided by the RSS of the three direction components, forms the y direction of the spacecraft thrust vector direction. |
| ZDirection | Default: 0. Options: [Real Number]: ZDirection , divided by the RSS of the three direction components, forms the z direction of the spacecraft thrust vector direction. |
| ThrustScaleFactor | Default: 1. Options: [Real Number > 0]: ThrustScaleFactor is a scale factor that is multiplied by the thrust vector for a given thruster, before the thrust vector is added into the total acceleration. Units: None. |
| Tank | Default: None. Options: [Tank Name]: The Tank field specifies which tank the thruster draws propellant from. |
| <p>The constants C_i below are used in the following equation to calculate thrust F_T as a function of pressure P and temperature T</p> $F_T(P, T) = \{C_1 + C_2P + C_3P^2 + C_4P^{C_5} + C_6P^{C_7} + C_8P^{C_9} + C_{10}C_{11}^{C_{12}P}\} \left(\frac{T}{T_{ref}}\right)^{1+C_{13}+C_{14}P}$ | |
| C1 | Default: 500. Options: [Real Number]: Thrust coefficient. Units: N |
| C2 | Default: 0. Options: [Real Number]: Thrust coefficient. Units: N/kPa. |
| C3 | Default: 0. Options: [Real Number]: Thrust coefficient. Units: N/kPa ² |
| C4 | Default: 0. Options: [Real Number]: Thrust coefficient. Units: N/kPa ^{C5} . |
| C5 | Default: 0. Options: [Real Number]: Thrust coefficient. Units: None |
| C6 | Default: 0. Options: [Real Number]: Thrust coefficient. Units: N/kPa ^{C7} . |
| C7 | Default: 0. Options: [Real Number]: Thrust coefficient. Units: None |
| C8 | Default: 0. Options: [Real Number]: Thrust coefficient. Units: N/kPa ^{C9} . |
| C9 | Default: 0. Options: [Real Number]: Thrust coefficient. Units: None |
| C10 | Default: 0. Options: [Real Number]: Thrust coefficient. Units: N. |
| C11 | Default: 1. Options: [Real Number]: Thrust coefficient. Units: None |
| C12 | Default: 0. Options: [Real Number]: Thrust coefficient. Units: 1/kPa. |
| C13 | Default: 0. Options: [Real Number]: Thrust coefficient. Units: None. |
| C14 | Default: 0. Options: [Real Number]: Thrust coefficient. Units 1/kPa. |

Table 2.6: Fields Associated with a Spacecraft Thruster
(Actuators Tab) (continued)

| Field | Options and Description |
|---|---|
| The constants K_i below are used in the following equation to calculate Isp as a function of pressure P and temperature T | |
| $I_{sp}(P, T) = \left\{ K_1 + K_2 P + K_3 P^2 + K_4 P^{K_5} + K_6 P^{K_7} + K_8 P^{K_9} + K_{10} K_{11}^{K_{12} P} \right\} \left(\frac{T}{T_{ref}} \right)^{1 + K_{13} + K_{14} P}$ | |
| K1 | Default: 2150. Options: [Real Number]: Isp coefficient. Units: m/sec |
| K2 | Default: 0. Options: [Real Number]: Isp coefficient. Units: m/(sec· kPa). |
| K3 | Default: 0. Options: [Real Number]: Isp coefficient. Units: m/(sec· kPa ²) |
| K4 | Default: 0. Options: [Real Number]: Isp coefficient. Units: m/(sec· kPa ^{K₅}). |
| K5 | Default: 0. Options: [Real Number]: Isp coefficient. Units: None |
| K6 | Default: 0. Options: [Real Number]: Isp coefficient. Units: m/(sec· kPa ^{K₇}). |
| K7 | Default: 0. Options: [Real Number]: Isp coefficient. Units: None |
| K8 | Default: 0. Options: [Real Number]: Isp coefficient. Units: m/(sec· kPa ^{K₉}). |
| K9 | Default: 0. Options: [Real Number]: Isp coefficient. Units: None |
| K10 | Default: 0. Options: [Real Number]: Isp coefficient. Units: m/sec. |
| K11 | Default: 1. Options: [Real Number]: Isp coefficient. Units: None |
| K12 | Default: 0. Options: [Real Number]: Isp coefficient. Units: 1/kPa. |
| K13 | Default: 0. Options: [Real Number]: Isp coefficient. Units: None. |
| K14 | Default: 0. Options: [Real Number]: Isp coefficient. Units 1/kPa. |

2.2 Propagator Fields

Table 2.7: Fields Associated with a Force Model

| Field | Options and Description |
|--|---|
| CentralBody | Default: Earth . Options: [Sun , Mercury , Venus , Earth , Luna , Mars , Jupiter , Saturn , Uranus , Neptune , Pluto]: The CentralBody field allows the user to select the origin for the propagation. All propagation occurs in the FK5 axes system, about the CentralBody chosen by the user. The CentralBody must be a gravitational body and so cannot be a LibrationPoint or other special point. Units: N/A. |
| PrimaryBodies | Default: { Earth }. Options: [Sun , Mercury , Venus , Earth , Luna , Mars , Jupiter , Saturn , Uranus , Neptune , Pluto]: The PrimaryBodies field is a list of all celestial bodies that are to be modelled with a force model more complex than point mass gravity. Lists are surrounded by curly braces. For each PrimaryBody , the user can choose a drag, magnetic field, and aspherical gravity model. There is a coupling between the PrimaryBodies field and the PointMasses field. A primary body can be any planet or moon not included in the PointMasses field. Units: N/A. |
| Gravity.PrimaryBody.PotentialFile | Default: JGM2 . Options: [CentralBody -based models, Other . See Comments]. This field allows the user to define the source for the non-spherical gravity coefficients for a primary body. If a gravity file is located in the Primary Body's potential path as defined in the startup file, you only need to specify the model name and not the entire path. For example, if the JGM2 coefficients file is contained in the directory defined in the startup file by the line EARTH.POT.PATH , then you only need to specify the model name JGM2 . If the model is not contained in the body's potential path, you must supply the entire path as well as the file name. If GMAT does not successfully find the file requested, it uses the default gravity model as defined in the startup file. From the GUI, only models for Earth appear if Earth is the active primary body. This is to avoid allowing the user to select a lunar potential model for the Earth. If the Other option is selected the user has the ability of selecting a gravity model file on their local computer. Units: None. |
| Gravity.PrimaryBody.Degree | Default: 4. Options: [Integer ≥ 0 and $<$ the maximum specified by the model, Order \leq Degree]. This field allows the user to select the the degree, or number of zonal terms, in the non-spherical gravity model. Ex. Gravity.Earth.Degree = 2 tells GMAT to use only the J2 zonal term for the Earth. The value for Degree must be less than the maximum degree specified by the Model. Units: None. |
| Gravity.PrimaryBody.Order | Default: 4. Options: [Integer ≥ 0 and $<$ the maximum specified by the model, Order \leq Degree]. This field allows the user to select the the order, or number of tesseral terms, in the non-spherical gravity model. Ex. Gravity.Earth.Order = 2 tells GMAT to use 2 tesseral terms. Note: Order must be greater than or equal to Degree . Units: None. |

Table 2.7: (Fields Associated with a Force Model...continued)

| Field | Options and Description |
|-----------------------------------|--|
| <code>Drag</code> | Default: <code>None</code> . Options: [<code>None</code> , <code>JachhiaRoberts</code> , <code>MSISE90</code> , <code>Exponential</code>]. The <code>Drag</code> field allows a user to specify a drag model. Currently, only one drag model can be chosen for a particular propagator and only Earth models are available. Units: N/A. <i>Note: This field will be deprecated in future versions of GMAT. Currently, the <code>Drag</code> field and the <code>Drag.AtmosphereModel</code> field must be set to the same value.</i> |
| <code>Drag.AtmosphereModel</code> | Default: <code>None</code> . Options: [<code>JachhiaRoberts</code> , <code>MSISE90</code> , <code>Exponential</code>]. The <code>Drag.AtmosphereModel</code> field allows a user to specify a drag model. Currently, only one drag model can be chosen for a particular propagator and only Earth models are available. Units: N/A. |
| <code>Drag.F107</code> | Default: 150. Options: [Real Number ≥ 0]. The <code>F107</code> field allows you to set the $F_{10.7}$ solar flux value used in computing atmospheric density. $F_{10.7}$ is the solar radiation at a wavelength of 10.7 cm. Units: $W/m^2/Hz$ |
| <code>Drag.F107A</code> | Default: 150. Options: [Real Number ≥ 0]. The <code>F107A</code> field allows you to set the average $F_{10.7}$ value. $\bar{F}_{10.7}$ is the average of $F_{10.7}$ over one month. Units: $W/m^2/Hz$ |
| <code>Drag.MagneticIndex</code> | Default:3. Options: [$0 \leq$ Real Number ≤ 9]: The <code>MagneticIndex</code> index field allows you to set the k_p value for use in atmospheric density calculations. k_p is a planetary 3-hour-average, geomagnetic index that measures magnetic effects of solar radiation. Units: None. |
| <code>SRP</code> | Default: <code>Off</code> . Options: [<code>On</code> , <code>Off</code>]. The <code>SRP</code> field allows the user to include the force due to solar radiation pressure in the total sum of forces. Units: N/A. |
| <code>PointMasses</code> | Default: <code>None</code> . Options [<code>Sun</code> , <code>Mercury</code> , <code>Venus</code> , <code>Earth</code> , <code>Luna</code> , <code>Mars</code> , <code>Jupiter</code> , <code>Saturn</code> , <code>Uranus</code> , <code>Neptune</code> , <code>Pluto</code>]. A <code>PointMass</code> is a planet or moon that is modelled by a point source located at its center of gravity. A <code>PointMass</code> body can be any planet or moon not included in the <code>PrimaryBodies</code> field. Units: N/A. |

Table 2.7: (Fields Associated with a Force Model...continued)

| Field | Options and Description |
|---------------------|--|
| ErrorControl | Default: RSSStep . Options: [RSSStep , RSSState , LargestState , LargestStep]: The ErrorControl field allows you to choose how a Propagator measures the error in an integration step. The algorithm selected in the ErrorControl field is used to determine the error in the current step, and this error is compared to the value set in the Accuracy field to determine if the step has an acceptable error or needs to be improved. All error measurements are relative error, however, the reference for the relative error changes depending upon the selection of ErrorControl . RSSState is the Root Sum Square (RSS) relative error measured with respect to the current step. RSSStep is the (RSS) relative error measured with respect to the current state. LargestStep is the state vector component with the largest relative error measured with respect to the current step. LargestState is the state vector component with the largest relative error measured with respect to the current state. For a more detailed discussion see the GMAT Mathematical Specification. Units: N/A. |

Table 2.8: Fields Associated with an Integrator

| Field | Options and Description |
|---|---|
| Fields associated with All Integrators | |
| Type | Default: RungeKutta89 . Options: [RungeKutta89 , RungeKutta68 , RungeKutta56 , PrinceDormand45 , PrinceDormand78 , BulirschStoer , AdamsBashforthMoulton]: The Type field is used to set the type of numerical integrator. Units: N/A. |
| InitialStepSize | Default: 60 (sec). Options: [Real Number]. The InitialStepSize is the size of the first attempted step by the integrator. If the step defined by InitialStepSize does not satisfy Accuracy , the integrator adapts the step according an algorithm defined in the mathematical specifications document to find an acceptable first step that meets the user's requested Accuracy . Units: sec. |
| Accuracy | Default: 1e-11. Options: [Real Number ≥ 0]. The Accuracy field is used to set the desired accuracy for an integration step. Units: N/A. When you set a value for Accuracy , GMAT uses the method selected in ErrorControl field on the Force Model, to determine a metric of the accuracy. For each step, the integrator ensures that the accuracy, as calculate using the method define by ErrorControl , is less than the limit defined by Accuracy . If an integrator exceeds MaxStepAttempts trying to meet the requested accuracy, and error message is thrown and propagation stops. |
| MinStep | Default: .001 (sec). Options: [Real Number > 0 , MinStep \leq MaxStep]. The MinStep field is used to set the minimum allowable step size. Units: sec. |
| MaxStep | Default: 2700.0 (sec.). Options: [Real Number > 0 , MinStep \leq MaxStep]. The MaxStep field is used to set the maximum allowable step size. Units: sec. |

Table 2.8: Fields Associated with an Integrator....(continued)

| Field | Options and Description |
|---|---|
| MaxStepAttempts | Default: 50. Options: [Integer > 0]. The MaxStepAttempts field allows the user to set the number of attempts the integrator takes to meet the tolerance defined by Accuracy . Units: None. |
| Fields associated only with Adams-Bashforth-Moulton Integrator | |
| MinIntegrationError | Default: 1.0e-13. Options: [Real Number > 0, MinIntegrationError < NomIntegrationError < Accuracy]: The MinIntegrationError field is used by the ABM integrator (and other predictor-corrector integrators when implemented) as the desired integration error to be obtained when the step size is changed. Predictor-Corrector integrators adapt step size when the obtained integration error falls outside of the range of acceptable steps, as determined by the bounds set by the MinIntegrationError and Accuracy fields. The integrator then applies an internal calculation to recompute the step size, attempting to hit the NomIntegrationError , and restarts the integrator. Units: N/A. |
| NomIntegrationError | Default: 1.0e-11. Options: [Real Number > 0, MinIntegrationError < NomIntegrationError < Accuracy]: The NomIntegrationError field is used by the ABM integrator (and other predictor-corrector integrators when implemented) as the desired integration error to be obtained when the step size is changed. Predictor-Corrector integrators adapt step size when the obtained integration error falls outside of the range of acceptable steps, as determined by the bounds set by the MinIntegrationError and Accuracy fields. The integrator then applies an internal calculation to recompute the step size, attempting to hit the NomIntegrationError , and restarts the integrator. Units: N/A. |
| Script Examples | |

Table 2.8: Fields Associated with an Integrator....(continued)

| Field | Options and Description |
|---|-------------------------|
| <pre> Create ForceModel MyProp_ForceModel; GMAT MyProp_ForceModel.CentralBody = Earth; GMAT MyProp_ForceModel.PrimaryBodies = {Earth}; GMAT MyProp_ForceModel.PointMasses = {Sun, Luna}; GMAT MyProp_ForceModel.Drag = None; GMAT MyProp_ForceModel.SRP = Off; GMAT MyProp_ForceModel.ErrorControl = RSSStep; GMAT MyProp_ForceModel.Gravity.Earth.Degree = 4; GMAT MyProp_ForceModel.Gravity.Earth.Order = 4; GMAT MyProp_ForceModel.Gravity.Earth.PotentialFile =/JGM2v; Create Propagator MyProp; GMAT MyProp.FM = MyProp_ForceModel; GMAT MyProp.Type = RungeKutta89; GMAT MyProp.InitialStepSize = 60; GMAT MyProp.Accuracy = 9.999999999999999e-012; GMAT MyProp.MinStep = 0.001; GMAT MyProp.MaxStep = 2700; GMAT MyProp.MaxStepAttempts = 50; </pre> | |

2.3 Maneuvers

Table 2.9: Fields Associated with an Impulsive Burn

| Field | Options and Description |
|---------------------|--|
| Origin | Default: Earth . Options: [Any celestial body]: Together the Origin and Axes fields describe the coordinate system in which a maneuver is applied. The Origin field determines the origin of the maneuver coordinate system. The ability to define the coordinate system locally avoids having to create many coordinate systems, associated with specific spacecraft, in order to perform finite maneuvers for multiple spacecraft. Units: N/A. |
| Axes | Default: VNB . Options: [VNB , MJ2000Eq]: The Axes field, together with the Origin field, describe the coordinate system in which an impulsive maneuver is applied. If VNB is chosen for Axes , a local coordinate system is created such that the x-axis points in the velocity direction of the spacecraft, with respect to the point defined by Origin , the y-axis points in the normal direction of the spacecraft with respect to Origin , and the z-axis completes the right-handed set. Units: N/A. |
| VectorFormat | Default: Cartesian . Options: [Cartesian , Spherical]: The VectorFormat field allows the user to define the format of the maneuver vector. Units: N/A. |
| Element1 | Default: 0. Options: [Real Number]: The Element1 field allows the user to define the first element of the impulsive maneuver vector. Element1 is <i>x</i> if VectorFormat is Cartesian . Element1 is the magnitude of the burn if VectorFormat is spherical . Units: km/sec. |

Table 2.9: (continued)

| Field | Options and Description |
|-----------------|---|
| Element2 | Default: 0. Options: [Real Number]: The Element2 field allows the user to define the second element of the impulsive maneuver vector. Element2 is y if VectorFormat is Cartesian . Units: km/sec. |
| Element3 | Default: 0. Options: [Real Number]: The Element3 field allows the user to define the second element of the impulsive maneuver vector. Element3 is z if VectorFormat is Cartesian . Units: km/sec. |

Table 2.10: Fields Associated with a Finite Burn

| Field | Options and Description |
|------------------------|--|
| Origin | Default: Earth . Options: [Any celestial body, libration point, or barycenter]: Together the Origin and Axes fields describe the coordinate system in which a maneuver is applied. The Origin field determines the origin of the maneuver coordinate system. The ability to define the coordinate system locally avoids having to create many coordinate systems, associated with specific spacecraft, in order to perform finite maneuvers for multiple spacecraft. Units: N/A. |
| Axes | Default: VNB . Options: [VNB , MJ2000Eq]: The Axes field, together with the Origin field, describe the coordinate system in which a finite maneuver is applied. If VNB is chosen for Axes , a local coordinate system is created such that the x-axis points in the velocity direction of the spacecraft, with respect to the point defined by Origin , the y-axis points in the normal direction of the spacecraft with respect to Origin , and the z-axis completes the right-handed set. Units: N/A. |
| Thrusters | Default: No Default. Options: [Any thruster created by user]: The Thrusters field allows the selection of which thrusters to use when applying a finite maneuver. The user can select more than one thruster, from the list of thrusters previously created, by including all thrusters in curly braces. An example is MyFiniteBurn.Thrusters = {Thruster1,Thruster2,Thruster3} . Units: N/A. |
| BurnScaleFactor | Default: 1.0 . Options: [Real Number]: The BurnScaleFactor is used to scale the total acceleration before adding the acceleration due to a finite burn into the sum of the accelerations of a spacecraft. The scaling is performed by taking the sum of the accelerations applied by all thrusters specified under the Thrusters field, and multiplying the total thrust by BurnScaleFactor . Units: None. |

2.4 Solver Fields

Table 2.11: Fields Associated with the fmincon Solver

| Field | Options and Description |
|-------|-------------------------|
|-------|-------------------------|

Table 2.11: (Fields Associated with the fmincon Solver....continued)

| Field | Options and Description |
|------------------------|--|
| DiffMaxChange | Default: 0.1 . Options: [Real Number > 0]: The DiffMaxChange parameter sets the upper limit on the perturbation used in MATLAB's finite differencing algorithm. For fmincon , you don't specify a single perturbation value, but rather give MATLAB a range, and it uses an adaptive algorithm that attempts to find the optimal perturbation. Units: N/A . |
| DiffMinChange | Default: 1e-8 . Options: [Real Number > 0]: The DiffMinChange parameter sets the lower limit on the perturbation used in MATLAB's finite differencing algorithm. For fmincon , you don't specify a single perturbation value, but rather give MATLAB a range, and it uses an adaptive algorithm that attempts to find the optimal perturbation. Units: N/A . |
| MaxFunEvals | Default: 1000. Options: [Integer > 0]: The MaxFunEvals parameter allows the user to set the maximum number of cost function evaluations in an attempt to find an optimal solution. This is equivalent to setting the maximum number of passes through an optimization loop in a GMAT script. If a solution is not found before the maximum function evaluations, fmincon outputs an ExitFlag of zero, and GMAT continues. Units: N/A. |
| MaxIter | Default: 400. Options: [Integer > 0]: The MaxIter parameter allows the user to set the maximum allowable number of optimizer iterations. Depending upon the nature of the problem, and whether gradients are provided, it may take many function evaluations for each optimizer iteration. The MaxIter parameter allows the user to control the maximum function evaluations, and maximum iterations independently. Units: N/A . |
| TolX | Default: 1e-4. Options: [Real Number > 0]: The TolX parameter is the termination tolerance on the vector of independent variables, and is used only if the user sets a value. Units: N/A. |
| TolFun | Default: 1e-4. Options: [Real Number > 0]: The TolFun parameter is the convergence tolerance on the cost function value. Units: N/A . |
| TolCon | Default: 1e-4 . Options: [Real Number > 0]: The TolCon parameter is the convergence tolerance on the constraint functions. Units: N/A . |
| DerivativeCheck | Default: off . Options: [on , off]: If the DerivativeCheck option is set to on , then fmincon will calculate the gradients of the cost and constraints using finite differencing, and compare the values to the values calculated analytically. Units: N/A . |
| Diagnostics | Default: off . Options: [on , off]: The Diagnostics parameter tells fmincon to output general information on the problem by writing diagnostic information to the MATLAB prompt. The diagnostic information contains the number of independent variables, the number and types of constraints, the sources for derivatives and other information. Units: N/A . |
| Display | Default: iter . Options: [off , on , iter , notify , final]: The Display parameter allows the user to select between several different options that displays information at the MATLAB prompt that indicates the progress of the optimization process. Units: N/A . |
| GradObj | Default: off . Options: [on , off]: The GradObj parameter allows the user to tell fmincon to use finite differencing to calculate the cost function derivative, or to use the cost function derivative provided by the user. Units: N/A . |
| GradConstr | Default: off . Options: [on , off]: The GradConstr parameter allows the user to tell fmincon to use finite differencing to calculate the constraint function derivatives, or to use the constraint function derivatives provided by the user. Units: N/A. |

2.5. PLOTS AND REPORTS

Table 2.11: (Fields Associated with the fmincon Solver....continued)

| Field | Options and Description |
|-------|-------------------------|
|-------|-------------------------|

Table 2.12: Fields Associated with a Differential Corrector

| Field | Options and Description |
|------------------------------|--|
| MaximumIterations | Default: 25. Options: [Integer > 0]: The MaximumIterations field allows the user to define the maximum number of iterations taken in attempt to find a solution. Units: N/A. |
| ShowProgress | Default: true . Options: [true , false]: When the ShowProgress field is set to true , then data illustrating the progress of the differential correction process are written to the status bar. The status bar is updated with information on perturbation and iteration passes. . Units: N/A. |
| ReportStyle | Default: Normal . Options: [Normal , Concise , Verbose , Debug]: The ReportStyle field allows the user to control the amount and type of information written to TargeterTextFile . Units: N/A. |
| TargeterTextFile | Default: DifferentialCorrectorDCName . Options: [Filename consistent with OS]: The TargeterTextFile field allows the user to specify the path and file name for the targeter report. Units: N/A. |
| UseCentralDifferences | Default: false Options: [true , false]: The UseCentralDifferences field allows the user to choose between one-sided and central differencing for determining the Jacobian matrix. If UseCentralDifferences is set to false, then one-sided differencing is used, if UseCentralDifferences is set to true, then central differencing is used. Units: N/A. |

2.5 Plots and Reports

Table 2.13: Fields Associated with OpenGL Plots

| Field | Options and Description |
|--|---|
| Fields associated with Plot Options | |
| ShowPlot | Default: true . Options: [true , false]: The ShowPlot field allows the user to turn off a plot for a particular run, without deleting the plot object, or removing it from the script. If you select true , then the plot will be shown. If you select false , then the plot will not be shown. Units: N/A. |

Table 2.13: (Fields Associated with OpenGL Plots....continued)

| Field | Options and Description |
|---|--|
| DataCollectFrequency | Default: 1. Options: [Integer ≥ 1]: The DataCollectFrequency field allows the user to define how data is collected for plotting. It is often inefficient to draw every ephemeris point associated with a trajectory. Often, drawing a smaller subset of the data still results in smooth trajectory plots, while executing more quickly. The DataCollectFrequency is an integer that represents how often to collect data and store for plotting. If DataCollectFrequency is 10, then Data is collected every ten integration steps. Units: Integration Steps |
| UpdatePlotFrequency | Default: 50. Options: [Integer ≥ 1]: The UpdatePlotFrequency field allows the user to specify how often to update an OpenGL plot is updated with new data collected during the process of propagating spacecraft and running a mission. Data is collected for a plot according the value defined by DataCollectFrequency . An OpenGL plot is updated with the new data, according to the value set in UpdatePlotFrequency . If UpdatePlotFrequency is set to 10, then the plot is updated with new data every ten integration steps. Units: Integration Steps. |
| NumPointsToRedraw | Default: 0. Options: [Integer ≥ 0]: When NumPointsToRedraw is set to zero, all ephemeris points are drawn. When NumPointsToRedraw is set to a positive integer, say 10 for example, only the last 10 collected data points are drawn. See DataCollectFrequency for explanation of how data is collected for an OpenGL plot. Units: Integration Steps. |
| Fields associated with Drawing Options | |
| WireFrame | Default: Off . Options: [On , Off]: When the WireFrame field is set to On , celestial bodies are drawn using a wireframe model. When the WireFrame field is set to Off , then celestial bodies are drawn using a full map. Units: N/A. |
| SolverIterations | Default: Off . Options: [On , Off]: The SolverIterations field determines whether or not perturbed trajectories are plotted during a solver (Targeter, Optimize) sequence. When SolverIterations is set to On , solver iterations are shown on the plot. When SolverIterations is Off , the solver iterations are not shown on the plot. Units: N/A. |
| EclipticPlane | Default: Off . Options: [On , Off , Note: Only allowed for OpenGL plots with Coordinate Systems that use the MJ2000Eq axis system]: The EclipticPlane field allows the user to tell GMAT to draw a grid representing the ecliptic plane in an OpenGL plot. Note, the ecliptic plane can currently only be drawn for plots whose coordinate system uses the MJ2000Eq axis system. Units: N/A . |
| XYPlane | Default: On . Options: [On , Off]: The XYPlane flag allows the user to tell GMAT to draw a grid representing the XY-plane of the coordinate system selected under the CoordinateSystem field of the OpenGL plot. Units: N/A . |
| Axes | Default: On . Options: [On , Off]: The Axis flag allows the user to tell GMAT to draw the Cartesian axis system associated with the coordinate system selected under the CoordinateSystem field of an OpenGL plot. Units: N/A . |
| Grid | Default: On . Options: [On , Off]: The Grid flag allows the user to tell GMAT to draw a grid representing the longitude and latitude lines celestial bodies added to an OpenGL plot. Units: N/A . |

Table 2.13: (Fields Associated with OpenGL Plots....continued)

| Field | Options and Description |
|---|---|
| EarthSunLines | Default: On . Options: [On,Off]: The EarthSunLines allows the user to tell GMAT to draw a line that starts at the center of Earth and points towards the Sun. Units: N/A . |
| Fields Associated with View Definition | |
| CoordinateSystem | Default: EarthMJ2000Eq . Options: [Any default or user defined coordinate system]: The CoordinateSystem field on an OpenGL plot allows the user to select which coordinate system to use to draw the plot data. A coordinate system is defined as an origin and an axis system, and the CoordinateSystem field allows the user to determine the origin and axis system of an OpenGL plot. See the CoordinateSystem object fields for information of defining different types of coordinate systems. Units: N/A. |
| Add | Default: DefaultSC , Earth . Options: [SpacecraftName CelestialBodyName LibrationPointName BarycenterName]: The Add subfield adds a spacecraft,celestial body, libration point,or barycenter to a plot. When creating a plot the Earth is added as a default body and may be removed by using the Remove command. The user can add a spacecraft, celestial body, libration point, or barycenter to a plot by using the name used to create the object. The GUI's Selected field is the equivalent of the script's Add field. In the event of no Add command or no objects in the Selected field, GMAT should run without the OpenGL plot and a warning message displayed in the message window. The following warning message is sufficient: OpenGL plot will be turned off. No object has been selected for plotting. Units: N/A. |
| Remove | Default: No Default. Options: [Any object included in the Add list]: The Remove subfield removes a spacecraft,celestial body, libration point, or barycenter from a plot. The user can remove any object that has been added to a plot by using the name used to add the object. Units: N/A. |
| ViewPointReference | Default: Earth . Options: [SpacecraftName CelestialBodyName LibrationPointName BarycenterName, or a 3-vector of numerical values]: The ViewPointReference field is an optional field that allows the user to change the reference point from which ViewPointVector is measured. ViewPointReference defaults to the origin of the coordinate system for the plot. A ViewPointReference can be any spacecraft, celestial body, libration point, or barycenter. Units: N/A. |
| ViewPointVector | Default: [0 0 30000]. Options: [SpacecraftName CelestialBodyName LibrationPointName BarycenterName, or a 3-vector of numerical values]: The product of ViewScaleFactor and ViewPointVector field determines the view point location with respect to ViewPointReference . ViewPointVector can be a vector, or any of the following objects: spacecraft,celestial body, libration point,or barycenter. The location of the Viewpoint in three-space is defined as the vector addition of ViewPointReference , and the vector defined by product of ViewScaleFactor and ViewPointVector in the coordinate system chosen by the user. Units: km or N/A. |

Table 2.13: (Fields Associated with OpenGL Plots....continued)

| Field | Options and Description |
|------------------------|--|
| ViewDirection | Default: Earth . Options: [SpacecraftName CelestialBodyName LibrationPointName BarycenterName , or a 3-vector of numerical values]: The ViewDirection field allows the user to select the direction of view in an OpenGL plot. The user can specify the view direction by choosing an object to point at such as a spacecraft, celestial body, libration point, or barycenter. Alternatively, the user can specify a vector of the form [x y z]. If the user specification of ViewDirection , ViewPointReference , and ViewPointVector , results in a zero vector, GMAT uses [0 0 10000] for ViewDirection . Units: km or N/A. |
| ViewScaleFactor | Default: 1. Options [Real Number ≥ 0]: The ViewScaleFactor field scales ViewPointVector before adding it to ViewPointReference . The ViewScaleFactor allows the user to back away from an object to fit in the field of view. Units: None. |

Fields Associated with View Up Definition

| | |
|-------------------------------|---|
| ViewUpCoordinateSystem | Default: EarthMJ2000Eq . Options: [Any default or user defined coordinate system]: The ViewUpCoordinateSystem and ViewUpAxis fields are used to determine which direction appears as up in an OpenGL plot and together with the fields associated with the View Direction, uniquely define the view. The fields associated with the View Definition allow the user to define the point of view in 3-space, and the direction of the line of sight. However, this information alone is not enough to uniquely define the view. We also must provide how the view is oriented about the line of sight. This is accomplished by defining what direction should appear as the up direction in the plot and is configured using the ViewUpCoordinateSystem field and the ViewUpAxis field. The ViewUpCoordinateSystem allows the user to select a coordinate system to define the up direction. Most of the time this system will be the same as the coordinate system chosen under the CoordinateSystem field. Units: N/A. |
| ViewUpAxis | Default: Z . Options: [X, -X, Y, -Y, Z, -Z]: The ViewUpAxis allows the user to define which axis of the ViewUpCoordinateSystem that will appear as the up direction in an OpenGL plot. See the comments under ViewUpCoordinateSystem for more details of fields used to determine the up direction in an OpenGL plot. Units: N/A. |

Fields Associated with Field of View

| | |
|-----------------------|--|
| UseInitialView | Default: On . Options: [On, Off]: The UseInitialView field allows the user to control the view of an OpenGL plot between multiple runs of a mission sequence. The first time a specific OpenGL plot is created, GMAT will automatically use the view as defined by the fields associated with View Definition, View Up Direction, and Field of View. However, if the user changes the view using the mouse, GMAT will retain this view upon rerunning the mission if UseInitialView is set to false . If UseInitialView is set to true , the view for an OpenGL plot will be returned to the view defined by the initial settings. Units: N/A. |
|-----------------------|--|

Table 2.13: (Fields Associated with OpenGL Plots....continued)

| Field | Options and Description |
|------------------------|---|
| PerspectiveMode | Default: Off . Options: [On , Off]: The PerspectiveMode field allows to user to toggle between the Orthogonal or Perspective projections. When PerspectiveMode is set to true , the Perspective projection is used. When PerspectiveMode is set to false , the Orthogonal projection is used. Units: N/A. |
| UseFixedFov | Default: Off . Options: [On , Off]: Units: N/A. |
| FixedFovAngle | Default: 45. Options: [Real Number ≥ 1]: Units: Degrees. |

Table 2.14: Fields Associated with Report Files

| Field | Options and Description |
|---------------------|--|
| FileName | Default: /RunReports/ReportFile1.txt . Options: [Valid File Path and Name]: The FileName field allows the user to define the file path and file name for a report. Units: None. |
| Precision | Default: 16. Options: [Integer > 0]: The Precision field allows the user to set the precision of the variable written to a report. Units: Same as variable being reported. |
| Add | Default: N/A. Options: [Any user-defined parameter. Ex. Variables, Arrays, S/C parameters]: The Add field allows a user to add user-defined variables to a report file. To add multiple user-defined variables, enclose the variables with curly brackets. Ex. MyReportName.Add = {Sat.X, Sat.Y, Var1, Array(1,1)} ; The GUI's Selected field is the equivalent of the script's Add field. In the event of no Add command or no objects in the Selected field, GMAT should run without the Report output and a warning message displayed in the message window. The following warning message is sufficient: Report plot will be turned off. No object has been selected for reporting. Units: N/A. |
| WriteReport | Default: On . Options: [On , Off]: The WriteReport field specifies whether to write data to the report FileName . Units: N/A. |
| WriteHeaders | Default: On . Options: [On , Off]: The WriteHeaders field specifies whether to include headers that describe the variables in a report. Units: N/A. |
| LeftJustify | Default: On . Options: [On , Off]: When the LeftJustify field is set to On , then the data is left justified and appears at the left most side of the column. If the LeftJustify field is set to Off , then the data is centered in the column. Units: N/A. |
| ZeroFill | Default: On . Options: [On , Off]: Units: N/A . |
| ColumnWidth | Default: 20. Options: [Integer > 0]: The ColumnWidth field is used to define the width of the data columns in a report file. The value for ColumnWidth is applied to all columns of data. For example, if ColumnWidth is set to 20, then each data column will be 20 white-spaces wide. Units: Characters. |

Table 2.14: Fields Associated with Report Files....(continued)

| Field | Options and Description |
|-------------------------|---|
| SolverIterations | Default: Off . Options: [On , Off]: The SolverIterations field determines whether or not data associated with perturbed trajectories during a solver (Targeter, Optimize) sequence is written to a report file. When SolverIterations is set to On , solver iterations are written to the report file. When SolverIterations is Off , the solver iterations are not written to the report file. Units: N/A. |

Table 2.15: Fields Associated with XY-Plots

| Field | Options and Description |
|-------------------------|---|
| IndVar | Default: DefaultSC.A1ModJulian . Options: [Any user variable, array element, or spacecraft parameter]: The IndVar field allows the user to define the independent variable for an xy-plot. Only one variable can be defined as an independent variable. For example, the line MyXYPlot.IndVar = DefaultSC.A1ModJulian sets the independent variable to be the epoch of DefaultSC in the A1 time system and modified Julian format. Units: N/A. |
| Add | Default: DefaultSC.EarthMJ2000Eq.X . Options: [Any user variable, array element, or spacecraft parameter]: The Add field allows the user to add dependent variables to an xy-plot. All dependent variables are plotted on the y-axis vs the independent variable defined by IndVar . To define multiple dependent variables, they should be included in curly braces. For example, MyXYPlot.Add = {DefaultSC.EarthMJ2000Eq.Y , DefaultSC.EarthMJ2000Eq.Z} ; . The GUI's Selected field is the equivalent of the script's Add field. In the event of no Add command or no objects in the Selected field, GMAT should run without the XYPlot and a warning message displayed in the message window. The following warning message is sufficient: XYPlot will be turned off. No object has been selected for plotting. Units: N/A. |
| Grid | Default: On . Options: [On , Off]: When the Grid field is set to On , then a grid is drawn on an xy-plot. When the Grid field is set to Off , then a grid is not drawn. Units: N/A. |
| SolverIterations | Default: Off . Options: [On , Off]: The SolverIterations field determines whether or not perturbed trajectories are plotted during a solver (Targeter, Optimize) sequence. When SolverIterations is set to On , solver iterations are shown on the plot. When SolverIterations is set to Off , solver iterations are not shown on the plot. Units: N/A. |
| ShowPlot | Default: true . Options: [true , false]: The ShowPlot field allows the user to turn off a plot for a particular run, without deleting the plot object, or removing it from the script. If you select true , then the plot will be shown. If you select false , then the plot will not be shown. Units: N/A. |

2.6 Solar System, Celestial Bodies and other Space Points

Table 2.16: Fields Associated with the Solar System

| Field | Options and Description |
|--------------------------------|---|
| EphemerisSource | Default: DE405 . Options: [DE405 , DE200 , SLP , Analytic]: The EphemerisSource field allows the user to select the source used for planetary ephemerides. The source is used globally whenever planetary ephemeris information is required. Units: None. |
| EphemerisUpdateInterval | Default: 0. Options: [Real Number ≥ 0]. The EphemerisUpdateInterval is used to set how often planetary positions are updated when calculating accelerations during propagation. For low-Earth orbits, EphemerisUpdateInterval can be set to around 60 for faster numerical integration with little effect on the accuracy of the propagation. For deep space propagation, EphemerisUpdateInterval should be set to zero. Units: sec. |
| UseTTForEphemeris | Default: false . Options: [true , false]: GMAT uses time in the TDB system as the default time system in the JPL ephemeris files. However, often it is possible to use time in the TT time system, without significant difference in propagation accuracy. (TT and TDB are within 1 millisecond of each other). The advantage to using TT is that it avoids the transformation from TT to TDB and therefore orbit propagation will execute faster. The UseTTForEphemeris field allows the user to choose between the default of TDB in the ephemeris files (UseTTForEphemeris =false), or TT in the ephemeris files (UseTTForEphemeris = true). Units: N/A. |
| EphemerisFile | Default: Same as startup file. Options:[File path and file name consistent with operating system]: The EphemerisFile field allows the user to specify the location and name of the file for each type of ephemeris GMAT supports. For example, if Ephemeris is set to DE405 , you can set the path for a DE405 file using SolarSystem.EphemerisFile = c:/MyPath/MyDE405.file . Units: N/A. |
| AnalyticModel | Default: LowFidelity . Options: [LowFidelity]: Units: N/A. |

Table 2.17: Fields Associated with a Libration Point

| Field | Options and Description |
|------------------|---|
| Primary | Default: Sun . Options: [Sun , Mercury , Venus , Earth , Luna , Mars , Jupiter , Saturn , Uranus , Neptune , Pluto , or any Barycenter. (The Primary and Secondary bodies cannot be the same)]: The Primary field tells GMAT which body to consider the primary body in the calculation of the location of a libration point. Units: N/A. |
| Secondary | Default: Earth . Options: [Sun , Mercury , Venus , Earth , Luna , Mars , Jupiter , Saturn , Uranus , Neptune , Pluto , or any Barycenter. (The Primary and Secondary bodies cannot be the same)]: The Secondary field tells GMAT which body to consider the secondary body in the calculation of the location of a libration point. Units: N/A. |
| Point | Default: L1 . Options: [L1 , L2 , L3 , L4 , L5]: The Point field specifies which libration point the object corresponds to. Units: N/A. |

Table 2.18: Fields Associated with a BaryCenter

| Field | Options and Description |
|-----------|---|
| BodyNames | Default: {Earth, Luna}. Options: [Sun, Mercury, Venus, Earth, Luna, Mars, Jupiter, Saturn, Uranus, Neptune, Pluto . (At least one body must be selected!)] : The BodyNames field is list that contains the bodies used to define a barycenter. In a script, the list must be surrounded by curly braces i.e. <code>BaryCenterName.BodyNames = {Earth, Luna} ;</code> Units: N/A. |

Table 2.19: Fields Associated with Celestial Bodies

| Field | Options and Description |
|---|--|
| Fields Associated with All Celestial Bodies. (Using Default Values for Earth as an Example) | |
| Mu | Default: 398600.4414. Options: [Real Number > 0]: The Mu field allows the user to define the gravitational paramter of a celestial body. Units: km ³ /sec ² . |
| Equatorial Radius | Default: 6378.1363. Options: [Real Number > 0]: The EquatorialRadius field allows the user to define the equatorial radius of a celestial body. Units: km. |
| Flattening | Default: 0.00335270. Options: [Real Number]: The Flattening field allows the user to define the mass of a celestial body. Units: None. |
| InitialEpoch | Default: 21544.500371. Options: [Real Number]: The InitialEpoch field allows the user to define the initial epoch, in A1 Modified Julian Date, for a celestial body. The initial epoch is only used when the user selects Analytic for the Ephemeris field on the solar system. In this case, GMAT solves Kepler's problem to determine the position and velocity of a celestial body, using the initial epoch and state information described below. Units: A1ModJulian. |
| SMA | Default: 149653978.978377. Options: [Real Number ≠ 0]: The SMA field allows the user to define the semimajor axis of a celestial body's orbit about its central body. (Only used when the user selects Analytic for the Ephemeris field on the Solar System.) Units: km. |
| ECC | Default: 0.017046. Options: [Real Number ≥ 0]: The ECC field allows the user to define the eccentricity of a celestial body's orbit about its central body. (Only used when the user selects Analytic for the Ephemeris field on the Solar System.) Units: None. |
| INC | Default: 23.439034. Options: [Real Number]: The INC field allows the user to define the inclination of a celestial body's orbit about its central body, in the FK5 coordinate system. (Only used when the user selects Analytic for the Ephemeris field on the Solar System.) Units: deg. |
| RAAN | Default: 0.000186. Options: [Real Number]: The RAAN field allows the user to define the right ascension of the ascending node of a celestial body's orbit about its central body, in the FK5 coordinate system. (Only used when the user selects Analytic for the Ephemeris field on the Solar System.) Units: deg. |

Table 2.19: (Fields Associated with Celestial Bodies...continued)

| Field | Options and Description |
|-------|--|
| AOP | Default: 101.741639. Options: [Real Number]: The AOP field allows the user to define the argument of periapsis of a celestial body's orbit about its central body, in the FK5 coordinate system. (Only used when the user selects Analytic for the Ephemeris field on the Solar System.) Units: deg. |
| TA | Default: 358.127085. Options: [Real Number]: The TA field allows the user to define the true anomaly of a celestial body's orbit about its central body. (Only used when the user selects Analytic for the Ephemeris field on the Solar System.) Units: deg. |

Special Fields Associated with Earth

| | |
|--------------------------------|---|
| NutationUpdate Interval | Default: 60. Options: [Real Number ≥ 0]: The NutationUpdateInterval field, on the Earth Celestial Body, determines how often GMAT updates the Nutation matrix used in FK5 reduction. If NutationUpdateInterval is set to zero, the Nutation is updated every time a request is made to calculate the orientation of the Earth. If NutationUpdateInterval is set to a real number greater than zero, then GMAT only updates the Nutation matrix if the number of seconds defined by NutationUpdateInterval have elapsed since the last request for the Earth's orientation data. Units: sec. |
|--------------------------------|---|

Special Fields Associated with Luna

| | |
|----------------------------|--|
| RotationData Source | Default: DE405. Options: [DE405, IAU2002]: The RotationDataSource , on the Luna Celestial Body, determines what source GMAT uses to obtain data describing the orientation of the moon with respect to the FK5 system. The RotationDataSource field is only used for lunar orientation data when calculating moon-based coordinate systems with the axes types of Fixed and Equator . Units: N/A |
|----------------------------|--|

Table 2.20: Fields Associated with a Coordinate System

| Field | Options and Description |
|----------------|--|
| Origin | Default: Earth . Options: [Any celestial body, barycenter, libration point, or spacecraft]: The Origin field allows the user to select the origin of a coordinate system. Units: N/A . |
| Axes | Default: MJ2000Eq . Options: [MJ2000Eq, MJ2000Ec, EarthFixed, BodyFixed, TOEEq, TOEEc, MOEEq, MOEEc, TODEq, TODEc, MODEq, MODEc, ObjectReferenced, Equator, BodyFixed, BodyInertial,GSE, GSM]: Units: N/A. |
| Primary | Default: Earth . Options: [Any celestial body, barycenter, libration point, or spacecraft, except the object chosen as in the Secondary field]: The Primary field is only active when Axes is set to ObjectReferenced . Otherwise, GMAT ignores the Primary field. Units: N/A . |

Table 2.20: (Fields Associated with a Coordinate System...continued)

| Field | Options and Description |
|-----------------------|--|
| Secondary | Default: Luna . Options: [Any celestial body, barycenter, libration point, or spacecraft, except the object chosen as in the Primary field]: The Secondary field is only active when Axes is set to ObjectReferenced . Otherwise, GMAT ignores the Secondary field. Units: N/A . |
| Epoch | Default: 21545.0. Options: [Real Number ≥ 0]: The Epoch field is only active if the Axes field is defined by an epoch referenced axis system: MOEEq , MOEEc , TOEEq , TOEEc . Units: Days . |
| XAxis | Default: R . Options: [R , -R , V , -V , N , -N]: The X field is only active if the Axes field is set to ObjectReferenced . Otherwise, GMAT ignores the X field. Units: N/A. |
| YAxis | Default: No Default. Options: [R , -R , V , -V , N , -N]: The Y field is only active if the Axes field is set to ObjectReferenced . Otherwise, GMAT ignores the Y field. Units: N/A. |
| ZAxis | Default: N . Options: [R , -R , V , -V , N , -N]: The Z field is only active if the Axes field is set to ObjectReferenced . Otherwise, GMAT ignores the Z field. Units: N/A. |
| UpdateInterval | Default: 60. Options: [Real Number ≥ 0]: Units: seconds. |

Table 2.21: Fields Associated with MATLAB Functions

| Field | Options and Description |
|---------------------|--|
| FunctionPath | Default: <code>\matlab\work</code> . Options: [Any valid path for Operating System]: Units: N/A. |

Chapter 3

Commands and Events

3.1 Propagation

Table 3.1: Propagate Command

| ScriptSyntax | |
|---|--|
| Propagate Mode BackProp <i>PropagatorName</i> (SatList1,{StopCondList1}) ... BackProp <i>PropagatorName</i> (SatListN,{StopCondListN}) | |
| Option | Option Description |
| BackProp | Default: None. Options: [Backwards or None]: The BackProp option allows the user to set the flag to enable or disable backwards propagation for all spacecraft in the the SatListN option. The Backward Propagation GUI check box field stores all the data in BackProp . A check indicates backward propagation is enabled and no check indicates forward propagation. In the script, BackProp can be the word Backwards for backward propagation or blank for forward propagation. Units: N/A. |
| Mode | Default: None. Options: [Synchronized or None]: The Mode option allows the user to set the propagation mode for the propagator that will affect all of the spacecraft added to the SatListN option. For example, if synchronized is selected, all spacecraft are propagated at the same step size. The Propagate Mode GUI field stores all the data in Mode . In the script, Mode is left blank for the None option and the text of the other options available is used for their respective modes. Units: N/A. |
| <i>PropagatorName</i> | Default: DefaultProp. Options: [Default propagator or any user-defined propagator]: The <i>PropagatorName</i> option allows the user to select a user defined propagator to use in spacecraft and/or formation propagation. The Propagator GUI field stores all the data in <i>PropagatorName</i> . Units: N/A. |
| SatListN | Default: DefaultSC. Options: [Any existing spacecraft or formations, not being propagated by another propagator in the same Propagate event. Multiple spacecraft must be expressed in a comma delimited list format.]: The SatListN option allows the user to enter all the satellites and/or formations they want to propagate using the <i>PropagatorName</i> propagator settings. The Spacecraft List GUI field stores all the data in SatListN . Units: N/A. |

Table 3.1: Propagate Command ...continued

| | |
|--|---|
| StopCondListN /Parameter | Default: DefaultSC.ElapsedSecs =. Options: [Any single element user accessible spacecraft parameter followed by an equal sign]. The StopCondListN option allows the user to enter all the parameters used for the propagator stopping condition. See the StopCondListN /Condition Option/Field for additional details to the StopCondListN option. Units: N/A. |
| StopCondListN /Condition | Default: 8640.0. Options: [Real Number, Array element, Variable, spacecraft parameter, or any user defined parameter]. The StopCondListN option allows the user to enter the propagator stopping condition's value for the StopCondListN Parameter field. Units: Dependant on the condition selected. |
| Script Examples | |
| % Single spacecraft propagation with one stopping condition | |
| % Syntax #1 | |
| Propagate DefaultProp(DefaultSC, {DefaultSC.ElapsedSecs = 8640.0}); | |
| % Single spacecraft propagation with one stopping condition | |
| % Syntax #2 | |
| Propagate DefaultProp(DefaultSC) {DefaultSC.ElapsedSecs = 8640.0}; | |
| % Single spacecraft propagation by one integration step | |
| Propagate DefaultProp(DefaultSC); | |
| % Multiple spacecraft propagation by one integration step | |
| Propagate DefaultProp(Sat1, Sat2, Sat3); | |
| % Single formation propagation by one integration step | |
| Propagate DefaultProp(DefaultFormation); | |
| % Single spacecraft backwards propagation by one integration step | |
| Propagate Backwards DefaultProp(DefaultSC); | |
| % Two spacecraft synchronized propagation with one stopping condition | |
| Propagate Synchronized DefaultProp(Sat1, Sat2, {DefaultSC.ElapsedSecs = 8640.0}); | |
| % Multiple spacecraft propagation with multiple stopping conditions and propagation settings | |
| % Syntax #1 | |
| Propagate Prop1(Sat1,Sat2, {Sat1.ElapsedSecs = 8640.0, Sat2.MA = 90}) ... | |
| Prop2(Sat3, {Sat3.TA = 0.0}); | |
| % Multiple spacecraft propagation with multiple stopping conditions and propagation settings | |
| % Syntax #2 | |
| Propagate Prop1(Sat1,Sat2) {Sat1.ElapsedSecs = 8640.0, Sat2.MA = 90} ... | |
| Prop2(Sat3) {Sat3.TA = 0.0}; | |

3.2 Control Flow

Table 3.2: If Command

| Script Syntax | |
|--|---|
| <i>(Simple If statement)</i> | |
| <pre>If <logical expression>; <Statements>; EndIf;</pre> | |
| <i>(Compound If statement)</i> | |
| <pre>If <logical expression> <logical expression> & <logical expression>; <Statements>; EndIf;</pre> | |
| <i>(If-Else statement)</i> | |
| <pre>If <logical expression>; <Statements>; Else; <Statements>; EndIf;</pre> | |
| Option | Option Description |
| <logical expression> | Default: DefaultSC.ElapsedDays < 1.0. Options:[Arg1 < Arg2 and < can be >, <, >=, <=, ==, ~=]. Arg1 and Arg2 can be any of the following: Real Number, Array element, Variable, Spacecraft Parameter or any other user defined parameter. Units: N/A. |
| <Statements> | Default: N/A. Options:[Any script line that can be in the mission sequence]. Units: N/A. |
| | Default: N/A. Options:[N/A]. The option allows the user to set an OR operator in between <logical expression>s. Units: N/A. |
| & | Default: N/A. Options:[N/A]. The & option allows the user to set an AND operator in between <logical expression>s. Units: N/A. |
| Script Examples | |
| <pre>If DefaultSC.ElapsedDays < 1; Propagate DefaultProp(DefaultSC , { DefaultSC.ElapsedDays = 0.01 }); EndIf;</pre> | |
| <pre>If MyVariable < MyArray(1,1); MyArray(1,1) = 5; EndIf;</pre> | |
| <pre>If DefaultSC.Earth.TA < MyArray(1,2); Propagate DefaultProp(DefaultSC); EndIf;</pre> | |

Table 3.3: While Command

| Script Syntax | |
|---|---|
| <i>(Simple While Loop)</i> | |
| <pre>While <logical expression>; <Statements>; EndWhile;</pre> | |
| <i>(Compound While Loop)</i> | |
| <pre>While <logical expression> <logical expression> & <logical expression> <Statements> EndWhile</pre> | |
| Option | Option Description |
| <logical expression> | Default: DefaultSC.ElapsedDays < 1.0. Options:[Arg1 < Arg2 and < can be >, <, >=, <=, ==, ~=]. Arg1 and Arg2 can be any of the following: Real Number, Array, Variable, Spacecraft Parameter or any other user defined parameter. Units: N/A. |
| <Statements> | Default: N/A. Options:[Any script line that can be in the mission sequence]. Units: N/A. |
| | Default: N/A. Options:[N/A]. The option allows the user to set an OR operator in between <logical expression>s. Units: N/A. |
| & | Default: N/A. Options:[N/A]. The & option allows the user to set an AND operator in between <logical expression>s. Units: N/A. |
| Script Examples | |
| <pre>While DefaultSC.ElapsedDays < 1; Propagate DefaultProp(DefaultSC , { DefaultSC.ElapsedDays = 0.01 }); EndWhile;</pre> | |
| <pre>While MyVariable < MyArray(1,1); MyArray(1,1) = 5; EndWhile;</pre> | |

Table 3.4: For Command

| Script Syntax | |
|---|--|
| <i>(Simple For Loop)</i> | |
| <pre>For <i>Variable</i> = Start:End; <Statements>; EndFor;</pre> | |
| <i>(Expanded For Loop)</i> | |
| <pre>For <i>Variable</i> = Start:Increment:End; <Statements>; EndFor;</pre> | |
| Command Description | |
| <p>The for loop is a control flow statement that allows portions of code to be executed iteratively using an explicit loop variable (Wikipedia). GMAT for loops are three-expression loops that allow the user to set the initial value of the loop variable, its increment, and the test to exit the loop. A parameter must be defined explicitly using a Create Variable statement or GUI equivalent before it can be used in a for loop command statement. The only parameter type that can be used as a loop variable is the variable type. The parameters used to define Start, Increment, and End can be any of the following GMAT parameters: integer??(real), variable, array element, spacecraft property.</p> <p>GMAT allows the for loop variable to be changed inside the loop by the user, and the resulting behavior of the for loop is equivalent to the behavior defined in ANSI C. If a change is made to the loop variable inside of the loop, if this change causes the exit test to be violated, GMAT will exit the for loop.</p> | |
| Option | Option Description |
| <i>Variable</i> | Default: No Default. Options:[<i>Variable</i>]: The <i>Variable</i> option allows the user to define the variable that will store the For Loop numeric range. Units: N/A. |
| Start | Default: 1. Options: [Real Number, Array element, Variable, or any user defined parameter]. The Start option allows the user to set the starting numeric range value of the For Loop. Start can be equal to End , but the For Loop will not execute. Units: N/A. |
| Increment | Default: 1. Options: [Real Number, Array element, Variable, or any user defined parameter]. The Increment option allows the user to set the numeric range increment value of the For Loop. When the Increment option is left out of the script syntax the default value is used. If an Increment value of 0 is used, the For Loop should not execute but GMAT should continue to run. If End>Start and Increment < 0 , then the For Loop should not execute. If Start>End and Increment > 0 , then the For Loop should not execute. Units: N/A. |
| End | Default: 10. Options: [Real Number, Array, Variable, or any user defined parameter]. The End option allows the user to set the ending numeric range value of the For Loop. End can be equal to Start , but the For Loop will not execute. Units: N/A. |
| Script Examples | |
| % Output the value of the For loop <i>Variable</i> to a file | |

Table 3.4: For Command ...continued

```
For I = 1:1:10;  
    GMAT testVar = I;  
    Report DefaultReportFile I;  
EndFor;
```

3.3 Solver-related

Table 3.5: Target Command

| Script Syntax | |
|---|---|
| <pre>Target <i>SolverName</i> ; <Statements> EndTarget;</pre> | |
| Option | Option Description |
| <i>SolverName</i> | Default: <code>DefaultDC</code> . Options:[Any differential corrector existing in the resource tree or created in the script]: The <i>SolverName</i> option allows the user to choose between any previously created differential correctors for use in a targeting sequence. For example, to begin a targeting sequence using <code>DefaultDC</code> , the script is <code>Target DefaultDC</code> . Units: N/A. |
| <Statements> | Default: None. Options:[Any non-targeter and non-optimizer command lines used in the mission sequence, as well as the targeter dependent command lines <code>Achieve</code> and <code>Vary</code> .]: Units: N/A. |
| Script Examples | |
| <pre>% Beginning and ending syntax for the Target command Target DefaultDC; EndTarget;</pre> | |

Table 3.6: Optimize Command

| Script Syntax | |
|---|---|
| <pre>Optimize <i>SolverName</i> ; <Statements> EndOptimize;</pre> | |
| Option | Option Description |
| <i>SolverName</i> | Default: <code>DefaultSQP</code> . Options:[Any existing optimizer]: The <i>SolverName</i> field allows the user to choose between any previously created optimizer for use in an optimization sequence. For example, to begin a optimization sequence using <code>DefaultSQP</code> , the script is <code>Optimize DefaultSQP</code> . Units: N/A. |
| <Statements> | Default: None. Options:[Any non-targeter and non-optimizer command lines used in the mission sequence, as well as the optimizer dependent command lines <code>Vary</code> , <code>NonLinearConstraint</code> , and <code>Minimize</code> .]: Units: N/A. |
| Script Examples | |
| <pre>% Beginning and ending syntax for the Optimize command Optimize DefaultDC;</pre> | |

Table 3.6: Optimize Command ...continued

```
EndOptimize;
```

Table 3.7: Achieve Command

```
ScriptSyntax: Achieve SolverName (Goal = Arg1, {Tolerance = Arg2});
```

| Option | Option Description |
|-------------------|--|
| <i>Goal</i> | Default: DefaultSC.Earth.RMAG. Options: [Spacecraft parameter, Array element, Variable, or any other single element user defined parameter, excluding numbers]: The <i>Goal</i> option allows the user to select any single element user defined parameter, except a number, to Achieve. |
| Arg1 | Default: 42165. Options: [Real Number, Array element, Variable, or any user defined parameter that obeys the conditions of Chapter ?? for the selected <i>Goal</i>] The Arg1 option is the desired value for <i>Goal</i> after the solver has converged. Units: N/A. |
| Tolerance | Default: 0.1. Options: [Real Number, Array element, Variable, or any user defined parameter > 0]: The Tolerance option sets Arg2. Arg2 is the convergence tolerance for Arg1. Units: N/A. |
| <i>SolverName</i> | Default: DefaultDC. Options: [Any user defined differential corrector]: The <i>SolverName</i> option allows the user to choose which solver to assign to the Achieve command. Units: N/A. |

Script Examples

```
Achieve DefaultDC(DefaultSC.Earth.RMAG = 42165.0, {Tolerance = 0.1});
```

Table 3.8: Vary Command

ScriptSyntax

```
Vary SolverName (Variable = InitialGuess, {Perturbation = Arg1, MaxStep = Arg2, Lower = Arg3,
... Upper = Arg4, AdditiveScaleFactor = Arg5, MultiplicativeScaleFactor = Arg6})
```

| Option | Option Description |
|--------|--------------------|
|--------|--------------------|

Parameters Associated with All Solvers.

| | |
|-------------------|--|
| <i>SolverName</i> | Default: DefaultDC. Options: [Any user defined solver]: The <i>SolverName</i> option allows the user to choose which solver to assign to the vary command. Units: N/A. |
|-------------------|--|

| | |
|-----------------|--|
| <i>Variable</i> | Default: DefaultIB.V. Options: [Spacecraft parameter, Array element, Variable, or any other single element user defined parameter, excluding numbers] The <i>Variable</i> option allows the user to select any single element user defined parameter, except a number, to vary. For example, DefaultIB.V, DefaultIB.N, DefaultIB.Element1, DefaultSC.TA, Array(1,1), and Variable are all valid values. The three element burn vector or multidimensional Arrays are not valid values. Units: N/A. |
|-----------------|--|

Table 3.8: Vary Command ...continued

| | |
|---------------------|--|
| InitialGuess | Default: 0.5. Options: [Real Number, Array element, Variable, or any user defined parameter that obeys the conditions of Chapter ?? for the selected <i>Variable</i>]: The InitialGuess option allows the user to set the initial guess for the selected <i>Variable</i> . Units: km/s. |
| Lower | Default: 0.0 . Options: [Real Number, Array element, Variable, or any user defined parameter (Upper > Lower)]: The Lower option allows the user to set Arg3 to the lower bound of the quantity being varied. Units: N/A. |
| Upper | Default: 3.14159 . Options: [Real Number, Array element, Variable, or any user defined parameter (Upper > Lower)]: The Upper option allows the user to set Arg4 to the upper bound of the quantity being varied. Units: N/A. |

Parameters Associated with Differential Corrector.

| | |
|---------------------|--|
| Perturbation | Default: 1e-4 . Options: [Real Number, Array element, Variable, or any user defined parameter > 0]: The Perturbation option is set by specifying a value for Arg1. The value of Arg1 is the perturbation size in calculating the finite difference derivative. Units: N/A. |
| MaxStep | Default: 0.2 . Options: [Real Number, Array element, Variable, or any user defined parameter > 0]: The MaxStep option is set by specifying a value for Arg2. The value of Arg2 limits the size of the step taken during an interaction of the differential corrector. Units: N/A. |

Parameters Associated with fmincon Optimizer.

| | |
|------------------------------------|---|
| Additive Scale Factor | Default: 0 . Options: [Real Number, Array element, Variable, or any user defined parameter]: The AdditiveScaleFactor Field is used to nondimensionalize the independent variable. fmincon sees only the nondimensional form of the variable. The nondimensionalization is performed using the following equation: $x_n = (x_d - a)/m$. (x_n is the non-dimensional parameter. x_d is the dimensional parameter. a = additive scale factor. m = multiplicative scale factor.) Units: N/A. |
| Multiplicative Scale Factor | Default: 1.0 . Options: [Real Number, Array element, Variable, or any user defined parameter]: The MultiplicativeScaleFactor Field is used to nondimensionalize the independent variable. fmincon sees only the nondimensional form of the variable. The nondimensionalization is performed using the following equation: $x_n = (x_d - a)/m$. (x_n is the non-dimensional parameter. x_d is the dimensional parameter. a = additive scale factor. m = multiplicative scale factor.) Units: N/A. |

Script Examples

```
% Impulsive Burn Vary Command
Vary DefaultDC(DefaultIB.V = 0.5, {Perturbation = 0.0001, MaxStep = 0.2, ...
Lower = 0, Upper = 3.14159});
```

Table 3.9: Minimize Command

Script Syntax: Minimize *OptimizerName* (*Arg*)

Table 3.9: Minimize Command ...continued

| Option | Option Description |
|---|--|
| <i>OptimizerName</i> | Default: SQP1. Options:[Any existing fmincon solver]: The OptimizerName option allows the user to specify which solver to use to minimize the cost function. Units: N/A. |
| Arg | Default: DefaultSC.ECC . Options:[Variable, Spacecraft parameter, or Array element]. The Arg field allows the user to specify the function to be minimized upon convergence of the solver given by <i>OptimizerName</i> . Arg can be any of the following: Variable, Array element, or Spacecraft Parameter or any other 1x1 numeric user defined parameter. Units: N/A. |
| Script Examples | |
| <pre>% Minimize the eccentricity of Sat, using fminconSQP Minimize fminconSQP(Sat.ECC);</pre> | |
| <pre>% Minimize the Variable DeltaV, using fminconSQP Minimize fminconSQP(DeltaV);</pre> | |
| <pre>% Minimize the first component of MyArray, using fminconSQP Minimize fminconSQP(MyArray(1,1));</pre> | |

Table 3.10: NonLinearConstraint Command

| | |
|---|--|
| Script Syntax: <code>NonLinearConstraint <i>OptimizerName</i> (<logical expression>)</code> | |
|---|--|

| Option | Option Description |
|----------------------|---|
| <i>OptimizerName</i> | Default: SQP1. Options:[Any existing fmincon solver]: The <i>OptimizerName</i> option allows the user to specify which solver to use in satisfying nonlinear constraints. Units: N/A. |
| <logical expression> | Default: DefaultSC.SMA = 7000. Options:[<i>Arg1</i> \leq <i>Arg2</i> where \leq can be \geq , \leq , $=$]. The logical expression field allows the user to specify the constraint to be satisfied upon convergence of the solver given by <i>OptimizerName</i> . <i>Arg1</i> and <i>Arg2</i> can be any of the following: Real Number, a 1-D Array (column vector), Array element, Variable, Spacecraft Parameter or any other numeric user defined parameter. If <i>Arg1</i> is a 1-D Array, then <i>Arg2</i> must be a 1-D Array with the same dimensions and vice-versa. Units: N/A. |

| Script Examples |
|-----------------|
|-----------------|

```
% Constrain the SMA of Sat to be 7000 km, using fminconSQP
NonLinearConstraint fminconSQP( Sat.SMA = 7000 );

% Constrain the SMA of Sat to be less than or equal to 7000 km, using fminconSQP
NonLinearConstraint fminconSQP( Sat.SMA <= 7000 );

% Constrain the SMA of Sat to be greater than or equal to 7000 km, using fminconSQP
NonLinearConstraint fminconSQP( Sat.SMA >= 7000a );
```

3.4 Miscellaneous

Table 3.11: Maneuver Command

| Script Syntax: Maneuver <i>BurnName</i> (<i>SpacecraftName</i>); | |
|--|--|
| Option | Option Description |
| <i>BurnName</i> | Default: <code>DefaultIB</code> . Options:[Any impulsive burn existing in the resource tree or created in the script]: The <i>BurnName</i> field allows the user to choose between any previously created impulsive burn. As an example, to maneuver <code>DefaultSC</code> using <code>DefaultIB</code> , the script line would appear as <code>Maneuver DefaultIB(DefaultSC)</code> . Units: N/A. |
| <i>SpacecraftName</i> | Default: <code>DefaultSC</code> . Options:[Any spacecraft existing in the resource tree or created in the script]: The <i>SpacecraftName</i> field allows the user to select which spacecraft to maneuver using the maneuver selected in the <i>BurnName</i> field. Units: N/A. |
| Script Examples | |
| % Impulsive Burn <code>Maneuver DefaultIB(DefaultSC);</code> | |

Table 3.12: BeginFiniteBurn Command

| Script Syntax: BeginFiniteBurn <i>ManeuverName</i> (<i>SpacecraftName</i>); | |
|--|---|
| Option | Option Description |
| <i>ManeuverName</i> | Default: <code>DefaultFB</code> . Options:[Any finite burn existing in the resource tree or created in the script]: The <i>ManeuverName</i> option allows the user to choose between any previously created finite burn. As an example, to maneuver <code>DefaultSC</code> using <code>DefaultFB</code> , the script line would appear as <code>Maneuver DefaultFB(DefaultSC)</code> . Units: N/A. |
| <i>SpacecraftName</i> | Default: <code>DefaultSC</code> . Options:[Any spacecraft existing in the resource tree or created in the script]: The <i>SpacecraftName</i> option allows the user to select which spacecraft to maneuver using the maneuver selected in the <i>ManeuverName</i> option. Units: N/A. |
| Script Examples | |
| % Default BeginFiniteBurn syntax <code>BeginFiniteBurn DefaultFB(DefaultSC);</code> | |

Table 3.13: EndFiniteBurn Command

Script Syntax: `EndFiniteBurn ManeuverName (SpacecraftName);`

| Option | Option Description |
|-----------------------|--|
| <i>ManeuverName</i> | Default: DefaultFB. Options:[Any finite burn existing in the resource tree or created in the script]: The <i>ManeuverName</i> option allows the user to choose between any previously created finite burn. As an example, to maneuver DefaultSC using DefaultFB, the script line would appear as <code>Maneuver DefaultFB(DefaultSC)</code> . Units: N/A. |
| <i>SpacecraftName</i> | Default: DefaultSC. Options:[Any spacecraft existing in the resource tree or created in the script]: The <i>SpacecraftName</i> option allows the user to select which spacecraft to maneuver using the maneuver selected in the <i>ManeuverName</i> option. Units: N/A. |

Script Examples

% Default EndFiniteBurn syntax
`EndFiniteBurn DefaultFB(DefaultSC);`

Table 3.14: CallFunction Command

Script Syntax

Function call with Inputs and Outputs

`GMAT [OutputList] = Function (InputList)`

Function call with Outputs only

`GMAT [OutputList] = Function`

Function call with Inputs only

`GMAT Function (InputList)`

Function call with no Inputs or Outputs

`GMAT Function`

| Option | Option Description |
|-------------------|---|
| OutputList | Default: None. Options:[Variables, Arrays, S/C Paramters, any other user-defined parameters, or blank. Multiple outputs must be expressed in a comma delimited list format]: The OutputList option allows the user to set the output of <i>Function</i> to a user defined parameter. Units: N/A. |
| InputList | Default: None. Options:[Variables, Arrays, S/C Paramters, any other user-defined parameters, or blank. Multiple inputs must be expressed in a comma delimited list format.]: The InputList option allows the user to set the input of <i>Function</i> to a user defined parameter. Units: N/A. |
| <i>Function</i> | Default: None. Options:[GMAT or Matlab Function]: The <i>Function</i> option allows the user to set the function that will be called in a specific location of the mission sequence. The function has to be defined before it can be used in the CallFunction Command. Units: N/A. |

Script Examples

Table 3.14: CallFunction Command ...continued

| |
|--|
| % Matlab function call without inputs or outputs |
| % Syntax 1 |
| GMAT clearAll; |
| |
| % Matlab function call without inputs or outputs |
| % Syntax 2 |
| GMAT [] = clearAll(); |

Table 3.15: Toggle Command

| Script Syntax: <code>Toggle <i>OutputNames</i> Arg</code> | |
|---|--|
| <hr/> | |
| Option | Option Description |
| <i>OutputNames</i> | Default: DefaultOpenGL . Options:[Any OpenGL, Report, XYplot, or any other Plot/Report type]: The Toggle option allows the user to assign the Plot/Report(s) to be toggled. When more than one Plot/Report is being toggled they need to be separated by a space. Units: N/A. |
| Arg | Default: On. Options:[On or Off]: The Arg option allows the user to turn off or on the data output to a Plot/Report. Units: N/A. |

| | |
|--|--|
| Script Examples | |
| <hr/> | |
| % Turn off Report file for the first day of propagation | |
| Toggle ReportFile1 Off | |
| Propagate DefaultProp(DefaultSC, DefaultSC.ElapsedDays = 1); | |
| Toggle ReportFile1 On | |
| Propagate DefaultProp(DefaultSC, DefaultSC.ElapsedDays = 1); | |
| | |
| % Turn off XYPlot and Report file for the first day of propagation | |
| Toggle XYPlot1 ReportFile1 Off | |
| Propagate DefaultProp(DefaultSC, DefaultSC.ElapsedDays = 1); | |
| Toggle XYPlot1 ReportFile1 On | |
| Propagate DefaultProp(DefaultSC, DefaultSC.ElapsedDays = 1); | |

Table 3.16: Report Command

Script Syntax: Report *ReportName* *DataList*

| Option | Option Description |
|-------------------|--|
| <i>ReportName</i> | Default: N/A. Options:[Any ReportFile created]: The ReportName option allows the user to specify the ReportFile for data output. Units: N/A. |
| <i>DataList</i> | Default: N/A. Options:[Spacecraft parameter, Array, Variable, String, or any other single user defined parameter]: The DataList option allows the user to output data to the Filename specified by the <i>ReportName</i> . Multiple objects can be in the <i>DataList</i> when they are separated by spaces. Units: N/A. |

Table 3.16: Report Command ...continued

| Script Examples |
|--|
| % Report the time and position of DefaultSC Report DefaultReport DefaultSC.A1ModJulian DefaultSC.X DefaultSC.Y DefaultSC.Z; |

Table 3.17: ScriptEvent Command

| Script Syntax | |
|--|--|
| <pre>BeginScript; <Statements>; EndScript;</pre> | |
| Option | Option Description |
| <Statements> | Default: N/A. Options:[Any valid line of GMAT script]. Units: N/A. |
| Script Examples | |
| <pre>% Assignment command inside Script Event BeginScript; GMAT testVar = 24; EndScript;</pre> | |

Table 3.18: Pause Command

| Script Syntax: Pause |
|---|
| Command Description |
| The Pause command allows the user to pause a running GMAT script. |
| Script Examples |
| % Pause between propagation sequences Propagate DefaultProp(DefaultSC) DefaultSC.ElapsedSecs = 8640.0; Pause; Propagate DefaultProp(DefaultSC) DefaultSC.ElapsedDays = 10.0; |

Table 3.19: Stop Command

| Script Syntax: Stop |
|---|
| Command Description |
| The Stop command allows the user to stop a running GMAT script. |
| Script Examples |
| % Stop between propagation sequences Propagate DefaultProp(DefaultSC) DefaultSC.ElapsedSecs = 8640.0; Stop; |

Table 3.19: Stop Command ...continued

```
Propagate DefaultProp(DefaultSC) DefaultSC.ElapsedDays = 10.0;
```

Table 3.20: Save Command

Script Syntax: Save *ObjectList*

| Option | Option Description |
|-------------------|---|
| <i>ObjectList</i> | Default: DefaultSC. Options:[Any user-defined objects, excluding variables and arrays]: The <i>ObjectList</i> option allows the user to save the properties of the objects selected to the output path. Multiple objects can be in the <i>ObjectList</i> when they are separated by spaces. Units: N/A. |

Script Examples

```
% Save DefaultSC data after a 1 day propagation
Propagate DefaultProp(DefaultSC, DefaultSC.ElapsedDays = 1);
Save DefaultSC;
% Save Impulsive Burn and DefaultSC data after a Targeter sequence
EndTargeter;
Save DefaultIB DefaultSC;
```

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